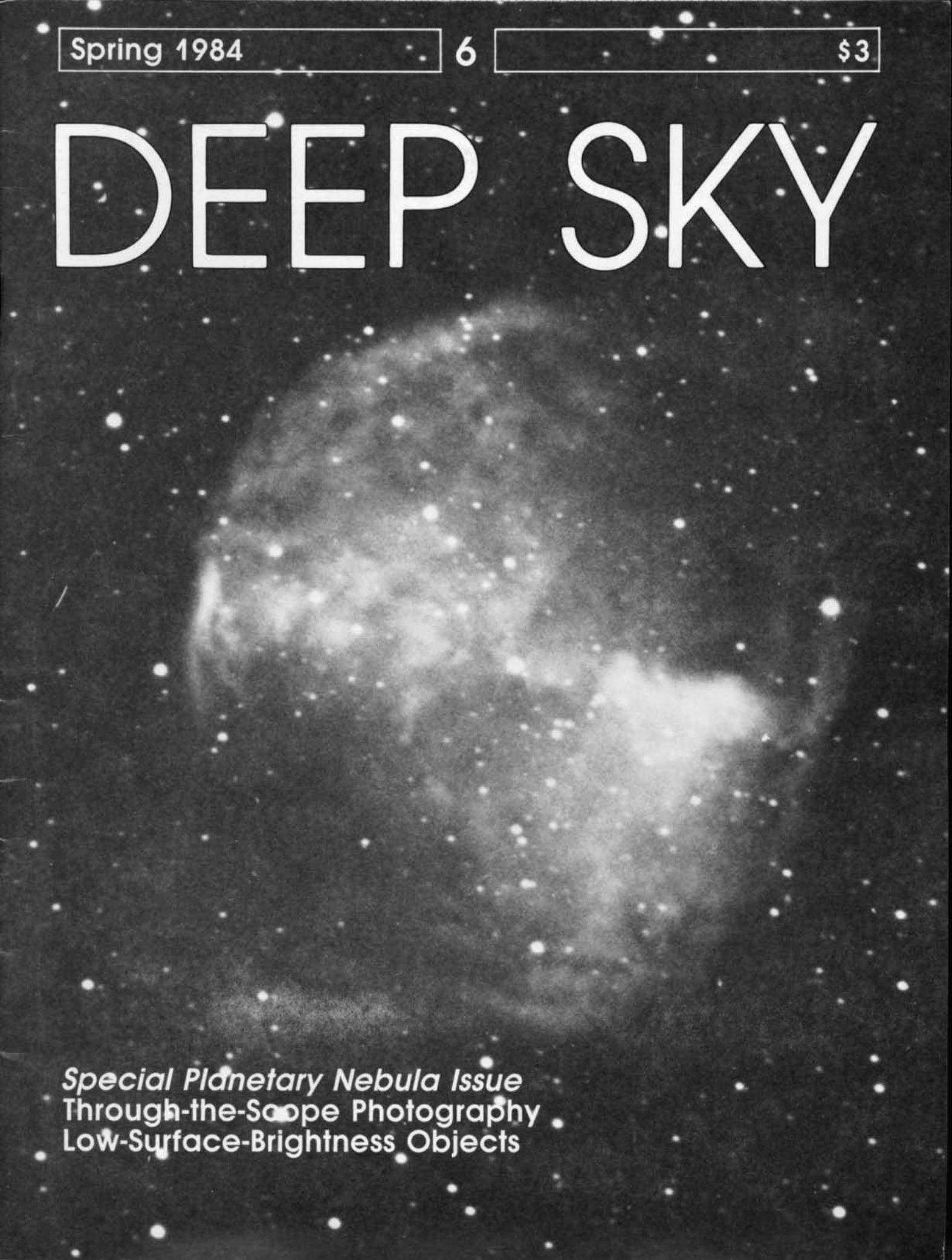
Spring 1984 | 6 | $3

DEEP SKY



Special Planetary Nebula Issue
Through-the-Scope Photography
Low-Surface-Brightness Objects

Letters to DSM

How Bright *Is* That Galaxy?

Dear Dave / Perhaps you can help me answer a question about brightnesses of galaxies. As I searched through the literature looking at magnitudes for various objects, some glaring inconsistencies arose. For example, the enclosed photo of the lovely edge-on spiral NGC 891 in Andromeda is listed as magnitude 12.2 in *Burnham's Celestial Handbook*. Apparently many of the "standard" magnitudes were derived from old Harvard plates, which give apparent photographic magnitudes and are at best uncertain. However, de Vaucouleurs' *Second Reference Catalogue of Bright Galaxies* (*RC2*) provides a blue (B) magnitude for NGC 891 of 10.90 ±0.08, based on accurate photoelectric and/or photographic photometry. The *RC2* also gives a B-V of 0.92 ±0.03, which results in a visual (V) magnitude of 9.98 ±0.11. A magnitude 9.98 object is very different from a magnitude 12.2 object — what is going on here? To best match what I see, do I use the B magnitude, the V magnitude, or part way in between?

As I understand it, the B magnitude peaks at about 440nm in the violet and the V magnitude at about 550nm in the green; the human rod response to faint light peaks at about 500nm in the blue-green.

Jack B. Marling
Lumicon, Inc.
2111 Research Drive
Livermore, CA 94550

Dear Jack / Your letter is a very timely one, as a lot of people seem to be thinking along the same lines these days. Large Dobsonians have made it clearer than ever that indeed major inconsistencies or omissions exist in the data, especially in the popular literature for amateur astronomers. As a general rule, the best source of magnitudes for galaxies is indeed the RC2, *where B and V magnitudes exist for most entries. The important bit of data — as total brightness goes — is the V magnitude, which most parallels human eye response and results in magnitude 9.87 to 10.09 for our sample galaxy. This range indicates the galaxy's true visual integrated magnitude if compressed into a point source.*

But galaxies are not point sources — rather they are spread out, making individual parts of them appear much dimmer than the whole. The California Nebula, for example, has a total magnitude of about 6 — yet is one of the most difficult objects to observe visually. The more pertinent piece of information is a galaxy's mean surface brightness, a measure of the average brightness of its little individual pieces when cut up into one square arcsecond or arcminute chunks. This figure more accurately represents what you see in a telescope than V magnitudes; actually, with faint stuff, you're interested in looking at the high end of the surface brightness rather than the mean, but they are usually fairly close. NGC 891's mean surface brightness is 13.8, accounting for its pale appearance in medium aperture scopes. This figure — a bit brighter than 14th magnitude — is more representative of 891 than its V

See Letters, page 4

Back Issues of *DEEP SKY MONTHLY*

Before there was DEEP SKY magazine, there was *Deep Sky Monthly*!

Before AstroMedia Corp. — publishers of ASTRONOMY — began publishing DEEP SKY, it existed as a 20-page monthly magazine for deep-sky observers, published by amateur astronomer Dave Eicher in Oxford, Ohio. *DSM* started out as a mimeographed newsleter in June 1977, and by March 1980 became a glossy magazine, complete with observing tips, maps, charts, astrophotos, and articles for observers and photographers in tune with the current state of deep-sky astronomy. The magazine ceased publication with the May 1982 issue, after five years — 60 issues — of production. Now you can buy back issues of *Deep Sky Monthly*, while they last, in a "publisher's closeout" of the *DSM* inventory. The main article in each issue is listed below: other features, illustrations, and articles also appear in each issue. To order, send $2 for each back issue you mark on the form (or on a copy of the form), and be sure to list second choices if some issues sell out before you get your copy.

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- ☐ #27/Aug '79: The Crab Nebula — I
- ☐ #28/Sept '79: The Crab Nebula — II
- ☐ #29/Oct '79: The 1979 Supernova in M100
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DEEP SKY 6

The magazine for deep-sky observers and astrophotographers

Spring 1984
Volume 2, Number 1

Cover: The Dumbbell Nebula, M27, photographed by Ron Potter; 14-inch f/11 SCT, hypersensitized TP 2415, 30-minute exposure.

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6 Observing Planetary Nebulae

by Dave Kratz

Planetary nebulae comprise one of the most interesting and varied classes of objects for backyard sky observers. Their unusual disk, ring, and amorphous shapes have assorted sizes and brightnesses, and many are visible in small telescopes even from good suburban locations. Tracking them down will give you valuable experience in locating small objects, distinguishing between colors, and using high magnifications to yield superior views of these little balls of hydrogen gas.

16 What Makes a Planetary Nebula?

by Francis Reddy

It is commonly thought that planetary nebulae form from old red-giant stars — but just how they do so is a complicated story. It involves stellar winds, stars gobbling their companions, and other factors that fit together in a mysterious way.

22 Astrophotography: Shooting Through the Scope

by David Healy

Much progress has been made recently in backyard astrophotography: equipment and techniques like Technical Pan 2415, deep-sky filters, hypersensitizing, emulsion chilling, and improved mounts and guiding systems now make it possible to create photos equalling observatory photos of a few years back. Our photography expert David Healy takes a look at some recent backyard shots and tells you how to match them.

30 Observing Low Surface Brightness Objects, Part One

by Jeffrey Corder and David J. Eicher

Observing handbooks of the past paint a dim picture of observing large nebulae, galaxies, and other low surface brightness objects. But contrary to popular belief, many targets known for their elusiveness can indeed be visually observed with the proper equipment and a dark sky site. They also pose several observing challenges which will tax the talents of the best deep-sky observers.

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Letters, cont. from page 2

magnitude of 10. I suspect that Burnham's figure of 12.2 is a guess, placed midway between the V magnitude and the mean surface brightness. You'll undoubtedly hear more about this dilemma in future DSMs, but for now suffice it to say that surface brightness represents what you see through a telescope better than total magnitude. — D.J.E.

Building Deep Sky Scopes

Dear Sir / I am a subscriber to three AstroMedia publications and am writing to let you know what a superb job you are doing with these fine magazines. Though I'm a beginner, I greatly enjoy tinkering with telescopes as well as looking at objects. Using an *Astronomy* article, I reworked a junked Tasco 2.4-inch refractor as my first telescope, adding a 1.25″ focuser. With information from *Telescope Making*, I made my second telescope — a 4.25-inch f/4 kit from Coulter — using Dobsonian techniques and shortcuts. It is now a joy to use.

My current project is a bit more ambitious and I have a couple of questions regarding the article by Richard Berry you printed in *Deep Sky* #5. I am readying the pitch lap for an 8-inch f/8 mirror and would like to incorporate Mr. Berry's suggestions into my telescope. If I use a closed tube design, can I narrow the tube's diameter to slightly larger than the mirror diameter to cut down mass, since air currents are no longer a problem? Could you please describe further what you mean by a "baffled tube bottom?" I plan on using a right angle prism — a 1.5-inch face tank prism — for the diagonal and would appreciate your comments on whether or not this is a good move. In the past I've heard both "pro" and "con" arguments.

I've enjoyed getting into astronomy "from the ground up," and have the fine folks at *Astronomy*, *Telescope Making*, and *Deep Sky* to thank for it. Keep up the good work!

Gary D. Jensen
1125 South Schaefer Street
Appleton, WI 54915

Mr. Jensen / Thanks for your letter. I am glad that you revitalized an old refractor with a new focuser tube. It really works! If the tube is closed with a window, the inside diameter of the tube is certainly less important than it is with an open tube. However, opinion varies on how close the tube wall should come under any circumstances. My guess is that the light path should never pass closer than ½″ of tube wall regardless, and for best results with an open tube, you should allow 1½″ or more. Remember, though, that unless the window is extremely good, it might degrade the image more than air currents in the tube.

If your primary purpose in building the scope is deep-sky observing, and portability is crucial, and the tube material is non-metal, then you may as well ignore the conventional wisdom and mount the mirror in a close-fitting tube. By baffling the bottom, I mean installing a ring at the bottom of the tube that's open in the middle to permit air circulation (if you close the front, then you must also close the back). The ring blocks light from the ground which comes around the edge of a conventional mirror cell between the mirror and the tube. I wouldn't recommend a tank prism without testing the flatness of its faces. These prisms were not intended for precision use, but some of them are pretty good anyhow. Once again, if you only want to do deep-sky observing, you might not notice the image degradation. Hope this helps — Richard Berry.

The NGC 3020 Galaxy Group

Dave / I thought readers might like to know about a fairly compact group of spiral galaxies I recently stumbled upon while observing in Leo. The brightest of the group, NGC 3020, is large and bright enough to be visible in a 5-inch refractor operating at 60x. The NGC 3020 group includes four objects, all with NGC numbers, within a 10′ diameter. Relevant data for the galaxies are given below in a table. There are no photoelectric measures, so the magnitudes come from the Zwicky catalogue (*Catalogue of Galaxies and Clusters of Galaxies*), which is close to the standard B system. Redshifts for the three brightest (Kirshner, 1977; *ApJ* **212**:319) show that NGC 3016 is a background object at more than six times the distance of the other two. Using a figure of 75 for the Hubble constant (H_0 = 75 Mpc/km/sec), the velocities correspond to distances of about 17 Mpc (about the same as the Virgo cluster) and 116 Mpc (farther than the Coma cluster).

I observed the group with the 24-inch f/8 Cassegrain at the U.S. Naval Observatory in Flagstaff, using a stop with an aperture equivalent to a 12.5-inch mirror. (Why I did this is another story!) I used a magnification of 250x, and seeing and transparency were very good. NGC 3020 showed a diffuse halo measuring 1.0′ x 0.5′ and broadly brighter across the center. The inner regions seemed granular, but there was no distinct nucleus.

NGC 3016, 8′ south-southwest of NGC 3020, is the co-dominant galaxy in the group. It appeared about 30″ across, and was slightly elongated east-northeast to west-southwest. The halo was weakly concentrated and I suspected a string of faint "stellarings" — mottling — along the major axis. About 6′ southeast of NGC 3020 is the edge-on galaxy NGC 3024. The elongation was clear, extending to about 1.0′ x 0.2′ in p.a. 125°; the halo didn't reach a magnitude 13.5 star 1.5′ southeast of the center. At the middle the distinctly brighter core bulges to perhaps 15″ width: this is a mini-4565, with narrow spike-like extensions as the halo. Just visible in the stopped-down telescope was NGC 3019, 4′ south of 3020, and forming a pair with a magnitude 13.5 star only 45″ northeast of it.

The three brightest members of this group are certainly visible in a 10-inch under good conditions. The granularity seen in NGC 3020 suggests that larger apertures might reveal a number of details. A good test for a 17.5-inch, Dave?

Brian Skiff
421 West Aspen
Flagstaff, AZ 86001

Name	R.A.(2000)Dec.	Mag.	Size	Type	Velocity (km/sec)
NGC 3016	9h49.8m +12°42′	13.7	1.2′x1.0′	Sb (UGC)	8701
NGC 3019	9h50.1m +12°44′	15.0	0.9′x0.6′	S (UGC)	——
NGC 3020	9h50.1m +12°49′	13.2	3.2′x1.8′	SB(r)cd	1282
NGC 3024	9h50.5m +12°46′	13.7	2.2′x0.6′	Sc: spindle	1364

Brian / Thanks for sharing the information regarding this unusual little group of galaxies. I'll be sure to investigate it when I get the Coulter 17.5-incher I ordered a few weeks ago. I'm already having dreams about 16th magnitude anonymous galaxies! — D.J.E.

Recent Imperfections

Dear Mr. Eicher / I absolutely love *Deep Sky* magazine. The articles are very informative and of good quality with a few imperfections. Let's start with two planetaries in Aquila, Minkowski 1-65 and Minkowski 1-74. In *Deep Sky* #3, you either reversed the coordinates or the symbols on the map on page 21. Which is correct? Also, in *Deep Sky* #4 — in Alan Goldstein's Local Group article — you mention two galaxies called only "Draco" and "Ursa Minor." Nothing is plotted at these positions on

Tirion's Sky Atlas 2000.0; what are these objects? You also show a system called "Maffei 1" on a chart but don't describe it; what is it?

Keith A. Swartz
95 Northeast 70th Avenue
Ankeny, IA 50021

Mr. Swartz / The two Minkowski planetaries had their labels switched; the correct coordinates are in the table, not the map. The Draco and Ursa Minor systems are dwarf galaxies in the Local Group whose large total magnitudes are immensely spread out, making them virtually impossible to detect by amateurs. The same holds true for Maffei 1, a large spiral in our Local Group: were it not behind the rich Cassiopeia Milky Way, it would shine at 6th magnitude and rival M33 — but it is heavily obscured and has a surface brightness of about 19. Thus it is impossible to observe, but you can photograph it — barely — with amateur instruments. It lies between the Double Cluster and the large emission nebulae IC 1805 and IC 1848, at 2h 36.3m, +59°39′ (2000.0). — D.J.E.

National Deep Sky Observers

Dear Dave / The National Deep Sky Observers Society — the country's sole organization devoted wholly to deep-sky observing — is holding a membership drive and organizing several projects leading up to our convention in Milwaukee with the Astronomical League. We think that DSM readers will be interested in hearing about our new observing clubs. The first is a group of dedicated observers aiming to observe at least 100 objects from the notoriously difficult *Index Catalogue*. Another group, involving people with large telescopes, will observe quasars, BL Lacertae objects, and other active galaxies. Those interested in a real challenge can attempt to observe 50 or more anonymous objects; ones with no standard identification number. Still another group will observe 100 or more Barnard dark nebulae.

If these observing projects sound interesting to your readers, have them get in touch with me. If any non-members wish to join the NDSOS, they can for $6 per year, which includes our bimonthly newsletter *Betelgeuse*. We are looking forward to meeting in Milwaukee and gaining many new energetic observers. Best of luck with the magazine!

Alan Goldstein
3430 Bryan Way
Lousiville, KY 40220

Alan / Thanks for letting readers know about new NDSOS projects. I'll be looking forward to seeing you and other deep-sky observers in August here in Milwaukee. — D.J.E.

Inside View

DSM Grows in Leaps and Bounds

This issue of DEEP SKY begins our second year of publishing a quarterly magazine for deep-sky observers and astrophotographers. I'm happy to report that your response to DSM has helped inject new vigor into its plans and goals: in one short year we've increased our circulation sixfold, increased our size to 40 pages, maintained high-quality paper and printing, and offered incisive articles on deep-sky objects — a few of which led to minor discoveries about the state of deep-sky observing. (More on that later.) We now have a circulation of 5,000+, ensuring that DSM will expand and further sharpen its content.

You may have already noticed that no advertising appears in this issue. Since the ads that appeared in DSM are not unique to deep-sky observers and all appear in the big astronomy publications, we've decided to abolish commercial advertising and convert DSM to a 100 percent pure, pristine editorial product — cover to cover. You may also have noticed that this issue contains *four*, not three, primary feature articles. The space saved from the ads, in my opinion, is much more valuable as another feature or added room in the departments. The extra 24 pages per year of editorial information will surely add to the magazine's usefulness. After all, most of the "suggestion box" letters I've received over the last year ask for a *bigger* DSM, and now you're getting just that.

This issue contains some pretty neat stuff: it is a special planetary nebula issue, beginning with Dave Kratz's lead feature on observing the little balls of hydrogen gas. Planetary nebulae are one of the most observed classes of sky objects, and this article provides information about, eyepiece sketches of, and amateur photos of the Ring, the Dumbbell, the Helix, the Owl, and many more. The observers I meet don't seem to tire of hunting planetaries, even if they've seen most of them available to their telescopes. The planetaries vary considerably in size, shape, color, and visible detail, which probably keeps them exciting for old-timers as well as neophytes. The second feature article, written by Frank Reddy of ASTRONOMY's staff, details recent thoughts about the astrophysics of planetary nebulae; this should keep you pondering as you look at them through your scope.

Continuing our series on astrophotography, this time David Healy details astrophotography through-the-telescope, offering tips on how to optimize your exposures with complex long focal ratio setups. And Jeff Corder, an experienced observer from North Carolina, has put together — along with your editor — a portfolio of some of the toughest visual targets for backyard telescopes. Jeff called me a few months ago and told me about his observations of some really faint stuff with 8- and 12.5-inch reflectors. I was impressed, and scheduled a two-part article (part two will appear in DSM 7). Let us know how you do with these objects — they range from relatively easy targets with low luminosities, like globular NGC 5897, to objects which may not even be visible regardless of instrument and sky, like reflection nebula IC 2118 in Eridanus.

In working on gathering data for the planetary nebula and low surface brightness articles, Brian Skiff of Lowell Observatory made me painfully aware of the poor state of data that exist for deep-sky objects. For many objects simple things like diameters and integrated magnitudes do not exist or are basically inaccurate estimates. In coming months (and years!) we will attempt to gather the best available data, providing what we believe are reasonable estimates where data do not exist. (The mean surface brightnesses in Jeff Corder's article, for example, are all estimated.) But in the mean time, realize that those data for the magnitude of such-and-such a nebula in *Burnham's*, and practically all of the other popular literature, are not to be trusted fully.

After a bit of a silence immediately following my move to Milwaukee, I am receiving plentiful photos and sketches again. Please keep them coming — with more pages and article topics in the future, we'll be happy to publish as much reader input as we can.

Warm regards,

Dave Eicher

Dave Eicher
Editor

OBSERVING

Planetary Nebulae

by Dave Kratz

During the summer of 1779, while casually scanning through Lyra with his 3-inch telescope, French astronomer Antoine Darquier discovered "a very dull nebula" which he further characterized as a "fading planet." Soon thereafter, fellow countryman and comet hunter Charles Messier included Darquier's nebula as the 57th item in his catalogue of objects not to be confused with comets. Now popularly known as the Ring Nebula, M57 is probably the best known example of a class of objects which are relatively scarce, exhibit a wide range of forms, and whose precise origins and evolution are still somewhat uncertain. Messier's catalogue also includes three other similar objects: M27 (the Dumbbell Nebula), which was discovered by Messier in 1764, and M76 (the Little Dumbbell Nebula) and M97 (the Owl Nebula) — both discovered by Pierre Mechain in 1780 and 1781 respectively.

In 1781 English astronomer William Herschel observed an object with a fuzzy greenish disk while making telescopic sweeps in Gemini — the planet Uranus. Four years later he noticed that a substantial number of the nebulae he found had appearances like that of Uranus, but fainter and fuzzier. This group of objects thus acquired the misnomer "planetary" nebulae — despite the fact that they have nothing whatsoever to do with planets. Astronomers continued to discover new examples of these nebulae into the 1800s, but they remained mysterious and inexplicable. In 1864, however, the English scientist William Huggins turned a spectroscope on NGC 6543, a bright planetary in Draco, and found an emission-line spectrum. This indicated the nebula was a hot, thin, luminous gas rather than the mass of unresolved faint stars which most observers had hitherto presupposed.

During the decades that followed Huggins' observations, astronomers found that spectroscopy was a powerful tool for determining the nature of a fuzzy patch in the sky. The *New General Catalogue* was compiled before this technique came into universal use and therefore the planetaries listed in the *NGC* tend to be large extended objects, whereas those which went into the later-compiled *Index Catalogues* include those which are more stellar in appearance. Many of these nebulae will appear stellar in your backyard telescope and are identifiable only by using considerable magnification, finder charts, spectroscopy, or by noting their telltale colors.

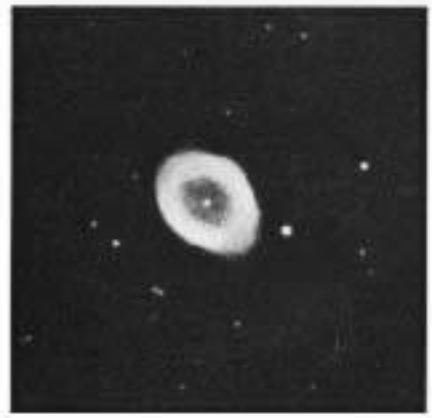
Since the turn of the century, astronomers have multiplied the number of known planetary nebulae rapidly. In 1918, a list of planetary nebulae compiled by Heber Curtis contained 102; 44 years later, Rudolph Minkowski proclaimed that 672 planetaries had been identified in the Milky Way. In 1967, the *Catalogue of Galactic Planetary Nebulae* by L. Perek and L. Kohoutek included 1036 objects. By 1981 astronomers estimated the total number of planetary nebulae within our Galaxy at 10,000 — a tenth of which (1346 to be exact) are known. The rest are obscured by interstellar gas clouds and pockets of dust strewn throughout the Milky Way.

A planetary nebula represents merely a chapter in the lifetime of certain stars. Nearly all Main-Sequence stars between one and five solar masses are destined to produce a planetary nebula at some point in later life. Identifying the precursors of planetary nebulae is a difficult job, but a wide variety of objects such as Mira-type variables, carbon stars, and symbiotic stars are possibilities.

While the precise mechanism by which planetary nebulae form is still under considerable debate (see "What Makes a Planetary Nebula?," page 16, this issue), the following scenario is a generally agreed on: as the star ages, hydrogen in its core becomes depleted. The star swells dramatically and

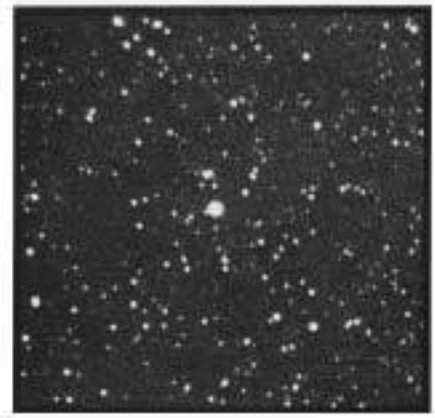
Martin Germano

M27 8-inch f/10 SCT
50 min., 103a-F



Alfred Lilge

M57 12.5-inch f/8 Newtonian
15 min., 103a-F



Lee Coombs

NGC 6826 10-inch f/5 Newtonian
10 min., 103a-E

All images have south at top, west at left

becomes a red giant. If the star is sufficiently massive, the helium "ash" left in the core from hydrogen burning also burns and combines to form heavier elements. In the meantime, the star's outer envelope diffuses, which continues until virtually all of the hydrogen is removed, leaving behind the very hot core. The envelope expands slowly and forms the nebula while the extremely hot core becomes the central star.

The process which makes a planetary nebula may occur in several stages, such as we see with objects such as NGC 6543 in Draco. This rather small bright planetary of magnitude 8.8 and 23″ x 18″ apparent size is centered in an extremely faint shell of gas approximately 4′ in diameter. This large diffuse wreath of material probably represents a very ancient episode when gas was ejected from the central star — something that occurred long before the formation of the present nebula. Even the Ring Nebula possesses a faint outer envelope extending to nearly twice the size of the bright nebulosity visible in small telescopes.

Planetary nebulae consist of a tenuous luminous gas cloud formed by the mass-ejection of the outer envelopes of a star, whose hot core becomes the central star. This rather mild process, as compared with the violence of a nova or supernova explosion, leaves behind a bluish dwarf or subdwarf star. Such stars are among the hottest known: their surface temperatures range from 25,000 °K to 120,000 °K; their absolute photographic magnitudes range from +1 to +9, with a mean value of +5, and their diameters vary from a hundredth that of the Sun to nearly the size of the Sun.

The nebula itself, with a typical mass of approximately one tenth of a solar mass and a density of around 10,000 atoms per cubic centimeter — more tenuous than the best laboratory vacuum on Earth — is characteristically highly excited by the large flux of ultraviolet radiation from the central star. Greatly rarefied, the gases of the nebula fluoresce and yield a narrow emission-line spectrum. The typical bluish-green appearance of a planetary nebula is the result of two strong emission lines of doubly-ionized oxygen, at 4959 Angstroms and 5007 A. These are atomic transitions which don't normally occur under conditions found in the laboratory and, at first, were attributed to a hypothetical element known as "nebulium." Further experiments showed that nebulium didn't exist — it is actually ordinary oxygen under extraordinary conditions.

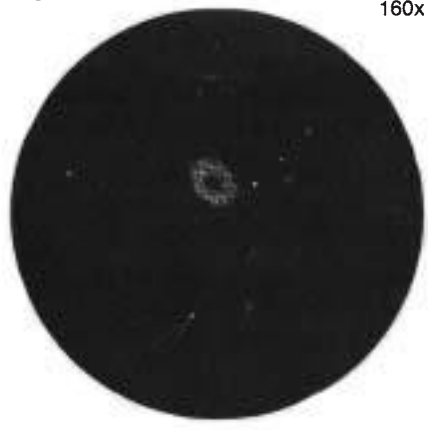
The average outward velocity of material in a planetary nebula is about 15 kilometers per second; this figure yields ages for the nebulae in the tens of thousands of years. Thus, by astronomical standards, planetary nebulae are evanescent, ephemeral objects destined to expand outward until they diffuse into invisibility some 30,000 to 40,000 years after they form. Therefore, new nebulae must be created continuously in order to account for the Galaxy's present population of them.

Often spectacular, planetary nebulae offer a variety of eyepiece views for backyard astronomers. Many of the planetaries are bright and display blue-green or blue color, so tracking them down becomes more a matter of your enthusiasm than the darkness of the site or the aperture of your telescope. As with all objects, however, the larger the aperture you use the greater the number of objects you'll find — all else being equal. The compactness of planetary nebulae also lets you put your higher eyepiece powers to use since

M27 21-inch f/5 Newtonian
112x

sketch by Alan Goldstein

M57 8-inch f/10 SCT
160x



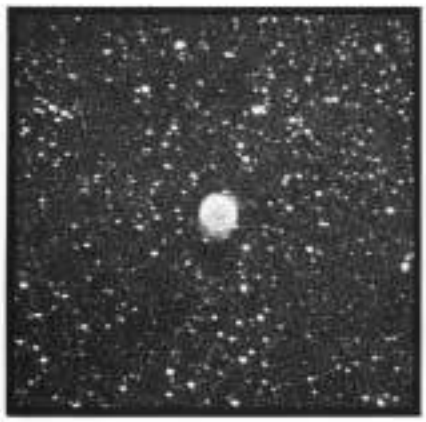
sketch by Danny Oakes

NGC 6826 21-inch f/5 Newtonian
225x

sketch by Alan Goldstein

IC 1454
Cepheus
NGC 6543
NGC 7139
Draco
NGC 7354
Hb 12
Ursa Major
M1-80
Lacerta
NGC 7008
IC 5217
NGC 6826
NGC 6833
NGC 7026
NGC 6884
NGC 7048
IC 5117
Canes Venatici
NGC 7662
NGC 7027
Cygnus
Lyra
NGC 6058
Hu 1-2
NGC 6881
Bootes
NGC 6857
M57
Hercules
NGC 6894
NGC 6765
NGC 6842
NGC 6939
Vulpecula
NGC 6210
Coma Berenices
M27
Hu 2-1
NGC 6905
NGC 6886
IC 4997
NGC 6879
Pegasus
Me 1-1
M1-74
NGC 7094
NGC 6891
IC 4593
NGC 6803
Cn 3-1
NGC 6804
Aquila
NGC 6807
NGC 6781
NGC 6572
NGC 6798
NGC 6852
Virgo
NGC 6778
NGC 6741
NGC 6772
NGC 6751
IC 4846
IC 1295
M1-59
Aquarius
NGC 7009
NGC 6309
NGC 6818
Ophiuchus
NGC 6567
NGC 6439
Libra
IC 972
NGC 6537
NGC 4361
NGC 6445
Capricornus
NGC 6578
IC 4732
6629
Hb 6
IC 4634
NGC 7293
Hb 4
NGC 6369
Me 2-1
Corvus
NGC 6644
NGC 6620
IC 4673
Sagittarius
NGC 6565
Hb 5
Piscis Austrinus
Hu 1-7
Scorpius
IC 4776
NGC 6563
Hb 8
NGC 6026
NGC 6072
NGC 6637
NGC 5873
IC 1297
IC 5148/50
NGC 6153
IC 4637
Corona Australis
IC 4406
Centaurus

Distribution of Planetary Nebulae
NGC 40
Cassiopeia
IC 1747
IC 289
NGC 1501
Hu 1-1
M97
NGC 2474/5
M2-2
M76
Lynx
IC 2149
Perseus
Auriga
IC 2120
Leo Minor
IC 351
IC 2003
NGC 1514
NGC 2371/2
M1-7
Triangulum
Gemini
Taurus
Aries
NGC 2392
J900
Ba 1
Leo
Cancer
J320
NGC 2022
Pisces
Canis Minor
NGC 2346
Orion
Monoceros
Cetus
IC 418
NGC 1535
NGC 246
Hydra
NGC 2438
IC 2165
NGC 2610
NGC 2440
Eridanus
NGC 3242
Puppis
Canis Major
NGC 1360
Fornax
NGC 2818
NGC 3132
Vela
Carina
Crux



Lee Coombs

NGC 6781 10-inch f/5 Newtonian
15 min., 103a-E

Jack Newton

NGC 7009 12.5-inch f/4.6 Newtonian
20 min., 103a-F

Lee Coombs

NGC 7293 10-inch f/5 Newtonian
20 min., 103a-E

these objects as a whole possess relatively high surface brightness — thus separating them from most extended objects (such as galaxies) which tend to fade into nothing at high power. But as with nearly everything, there's always an exception or two — for instance, the Helix Nebula (NGC 7293) in Aquarius, which measures 900″ x 720″ and which demands low powers and extremely transparent skies. The vast majority of planetaries, however, are less than 30″ in diameter.

Usually, you can find planetary nebulae with angular dimensions greater than 10″ by means of standard star-hopping techniques. Nebulae smaller than 10″, however, often prove to be troublesome because many are identifiable only by their color. Finder charts such as those in volume 2 of the Webb Society's *Deep-Sky Observer's Handbook* or in Perek and Kohoutek's *Catalogue of Galactic Planetary Nebulae* are an enormous assistance. And keep in mind that the drawings you see published reflect some individual's eyepiece impression and will probably include distortion. Nor are photographs always a help, since they rarely correspond completely to visual observations.

To observe the tiniest planetary nebulae, you may wish to hold a prism or small piece of replica diffraction grating (such as are sold by Edmund Scientific) between the eyepiece and your eye. These work by spreading the light of the objects in the field of view into their individual spectra. Stars, which emit light of essentially all colors, become narrow rainbow streaks, while planetary nebulae, emitting at discrete wavelengths, appear as a series of discrete stellar images. For most planetary nebulae only the two forbidden lines of doubly-ionized oxygen (at 4959 A and 5007 A) show as a single unresolved stellar image. This is because the two emission features are of a color much more visible to the human eye than any other emission feature, and because they are sufficiently close to one another in wavelength that the grating's small dispersion can't separate them.

Another technique I find useful is a narrow-bandpass nebular filter, which also makes use of the fact that planetary nebulae possess emission line spectra. First, you locate the suspected planetary and compare its apparent magnitude with the apparent magnitudes of the field stars. Then, after placing the nebular filter into the eyepiece, you repeat the observation. Since the field stars posseses broadband spectra, a significant quantity of their light will be filtered out; the nebular light, however, passes virtually unattenuated. The result is that the planetary nebula appears to "pop" relative to the field stars.

The lines of doubly-ionized oxygen give most planetary nebulae a distinctive bluish, bluish-green, or greenish tint. You can use this to pick a planetary nebula out from the field stars. For instance, NGC 6818 — a 10th magnitude planetary in Sagittarius measuring 22″ x 15″ — is visible at low powers (30x, say) despite a small size because of its distinctive bluish tinge. Many planetary nebulae also show a disklike appearance not unlike Uranus or Neptune which is helpful in distinguishing them from background stars. Indeed, at opposition Uranus shines at magnitude 5.8 and spans 3.8″ across and Neptune glows at magnitude 7.7 and measures 2.5″; both make nice "warm-up" objects for planetary nebula hunting.

You'll also need a good set of star charts and the knowledge of how to use them. The overwhelming best choice is

NGC 6781 8-inch f/5 Newtonian
70x

sketch by David J. Eicher

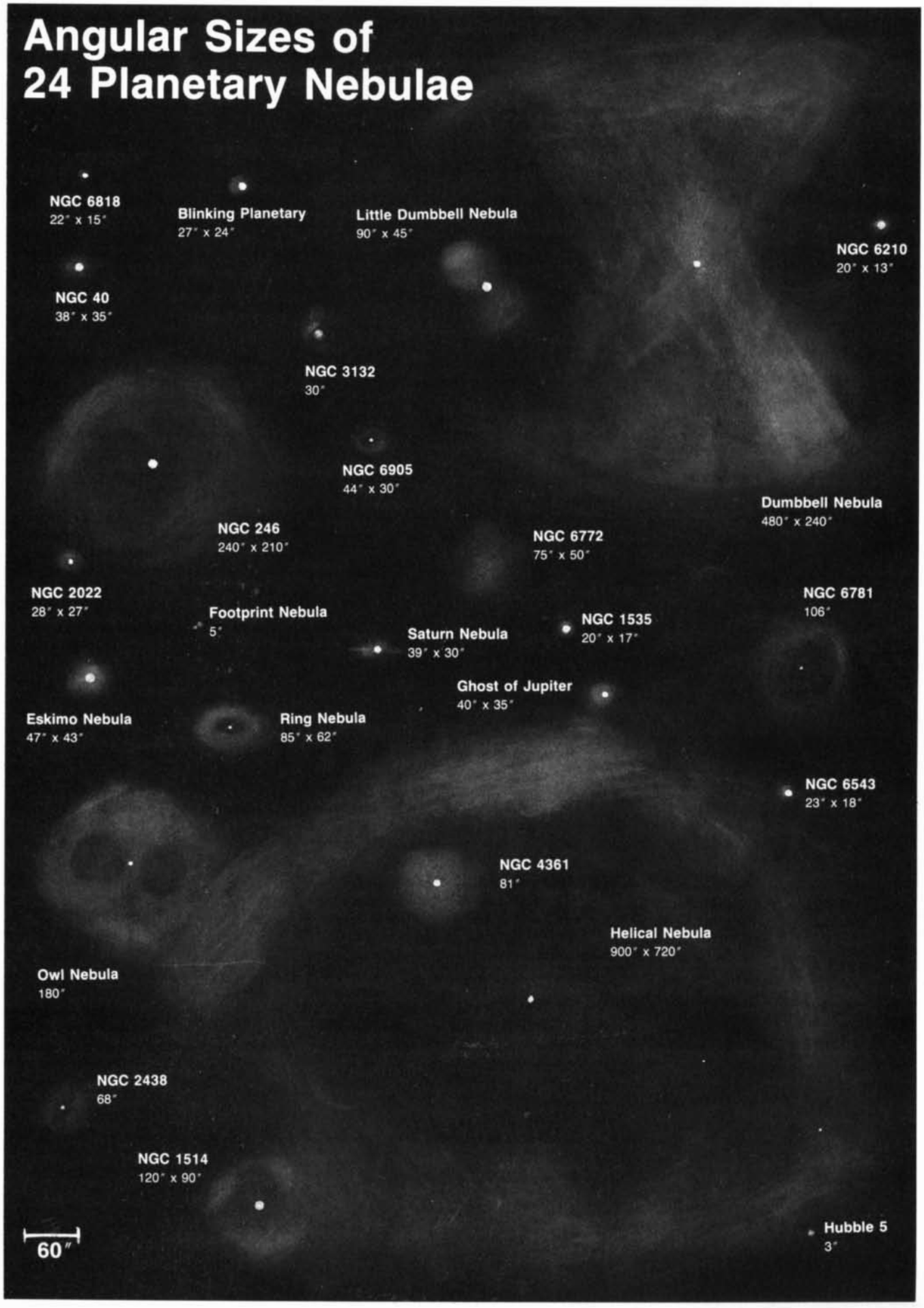
NGC 7009 6-inch f/8 Newtonian
120x

sketch by Randy Lutz

NGC 7293 6-inch f/8 Newtonian
70x

sketch by Chesley Runyon, Jr.

Angular Sizes of 24 Planetary Nebulae



Planetary Nebulae

for Backyard Telescopes

Object	M#	R.A.(2000)Dec.	Mag.	Mag.*	Size	Type	Con
NGC 40		00h13.0m +72°32′	10.7p	10.0	38″x35″	IIIb+III	Cep
Humason 1-1		00h28.2m +55°57′	13.3p	16.5	5″	II	Cas
NGC 246		00h47.0m −11°53′	8.0p	12.0	240″x210″	IIIb	Cet
NGC 650/651	M76	01h42.3m +51°34′	12.2p	16.3	90″x45″	III+VI	Per
IC 1747		01h57.6m +63°20′	13.6p	15.4	13″	IIIb	Cas
IC 289		03h10.3m +61°20′	12.3p	15.5b	45″x30″	IV+II	Cas
NGC 1360		03h33.4m −25°51′	7.0	11.4	460″x320″	III	For
IC 351		03h47.5m +35°03′	12.4p	15.0p	8″x6″	IIa	Per
Baade 1		03h53.5m +19°28′	13.9p	17.1p	38″	IV	Tau
IC 2003		03h56.4m +33°52′	12.6p	15.4	7″	II	Per
NGC 1501		04h07.0m +60°55′	11.3	14.2	56″x48″	III	Cam
NGC 1514		04h09.2m +30°47′	10.8	9.4	120″x90″	III+II	Tau
Minkowski 2-2		04h13.3m +56°57′	—	—	12″x11″	III	Cam
NGC 1535		04h14.3m −12°45′	10.8	11.6	20″x17″	IV+VI	Eri
Jonckheere 320		05h05.6m +10°42′	12.9p	14.4	11″x8″	II	Ori
IC 2120		05h18.2m +37°36′	12.0	16.2	50″	II	Aur
IC 418		05h27.6m −12°46′	12.0	9.0	14″x11″	IV	Lep
NGC 2022		05h42.2m +09°05′	12.3p	14.9	28″x27″	IV+II	Ori
IC 2149		05h56.3m +46°07′	11.2p	10.5p	12″x6″	IIIb+I	Aur
IC 2165		06h21.8m −12°59′	12.5p	15.1	9″x7″	IIIb	CMa
Jonckheere 900		06h26.0m +17°47′	12.4p	15.3	12″x10″	IIIb+II	Gem
Minkowski 1-7		06h37.4m +24°01′	—	—	38″x20″	II	Gem
NGC 2346		07h09.4m −00°48′	12.5	var.	60″x50″	IIIb+VI	Mon
NGC 2371/2372		07h25.5m +29°29′	10.8	14.8	54″x35″	IIIa+II	Gem
NGC 2392		07h29.1m +20°55′	9.7	10.4	47″x43″	IIIb	Gem
NGC 2438		07h41.9m −14°44′	11.0	17.7	68″	IV	Pup
NGC 2440		07h41.9m −18°12′	11.4	14.0	54″x20″	V+III	Pup
NGC 2452		07h47.4m −27°30′	12.6p	19.0p	22″x16″	IV+III	Pup
PK 164+31°1		07h57.8m +53°25′	14.0p	16.0	450″x400″	IV	Lyn
NGC 2610		08h33.4m −16°09′	13.6p	15.5p	38″x31″	IV+II	Hya
NGC 2818		09h16.0m −36°37′	13.0p	17.5	40″	IIIb	Pyx
NGC 3132		10h07.0m −40°26′	8.2	8.8	30″	IV+II	Vel
NGC 3242		10h24.8m −18°38′	8.8	11.7	40″x35″	IV+IIIb	Hya
NGC 3587	M97	11h14.8m +55°00′	12.0p	16.0	180″	IIIa	UMa
NGC 4361		12h24.5m −18°48′	10.3	13.0	81″	IIIa+II	Crv
IC 3568		12h32.9m +82°33′	9.0p	12.4	15″	II+IIa	Cep
IC 972		14h04.4m −17°15′	14.9	17.3	47″	IIb	Vir
IC 4406		14h22.5m −43°41′	10.6p	17.0p	100″x37″	IV+III	Lup
NGC 5873		15h12.9m −38°06′	13.3p	—	3″	II	Lup
Merrill 2-1		15h22.3m −23°38′	—	16.7	6″	II	Lib
NGC 6026		16h01.3m −34°33′	—	—	54″x36″	IV	Lup
NGC 6058		16h04.4m +40°41′	13.3p	13.7	25″x20″	III+II	Her
IC 4593		16h12.3m +12°04′	11.4p	11.2	15″x11″	II+II	Her
NGC 6072		16h13.0m −36°14′	14.1p	17.5p	50″x30″	IIIa	Sco
NGC 6153		16h31.4m −40°14′	11.5p	—	25″	IV	Sco
NGC 6210		16h44.5m +23°48′	9.7p	12.3	20″x13″	II+IIIb	Her
IC 4634		17h01.6m −21°40′	12.3p	17.4p	10″x7″	IIa+III	Oph
IC 4637		17h05.2m −40°53′	13.6	—	21″x17″	III	Sco
NGC 6309		17h14.1m −12°54′	11.7	14.4	22″x12″	IIIb+VI	Oph
NGC 6337		17h22.2m −38°29′	—	16.0	40″	IV	Sco
NGC 6369		17h29.3m −23°45′	10.4p	16.0p	28″	IV+II	Oph
Hubble 4		17h42.0m −24°43′	13.6	—	5″	IIIb	Oph
Hubble 5		17h47.9m −30°00′	12.0	—	3″	II+VI	Sgr
NGC 6439		17h48.3m −16°29′	13.8	18.0	5″	IIa	Sgr
NGC 6445		17h49.3m −20°01′	9.5	19.1p	38″x29″	IIIb+III	Sgr
Hubble 6		17h55.1m −21°45′	13.6	14.0	5″	II	Sgr
NGC 6543		17h58.6m +66°38′	8.3	10.9	23″x18″	IIIa+II	Dra
IC 4673		18h03.3m −27°06′	—	—	16″	IV	Sgr
NGC 6537		18h05.3m −19°51′	12.5	—	5″	IIa+VI	Sgr
NGC 6565		18h11.9m −28°10′	13.2	—	10″x8″	IV	Sgr
NGC 6563		18h12.0m −33°52′	12.0p	18.0p	50″x37″	IIIa	Sgr
NGC 6572		18h12.1m +06°51′	9.0p	9.8p	14″x9″	IIa	Oph
NGC 6567		18h13.8m −19°04′	11.7p	15.0p	11″x7″	IIa+III	Sgr
NGC 6578		18h16.3m −20°27′	13.1	—	8″	IIa	Sgr
Cannon 3-1		18h17.6m +10°09′	11.8	—	7″	II	Oph
NGC 6620		18h22.9m −26°50′	15.0	—	5″	IIb	Sgr
NGC 6629		18h25.7m −23°12′	10.8	13.0	16″x14″	IIa	Sgr
NGC 6644		18h32.6m −25°08′	12.2	—	3″	II	Sgr
IC 4732		18h34.0m −22°28′	13.3	—	3″	I	Sgr
Minkowski 1-59		18h43.3m −09°05′	—	—	5″	II	Sct

Object	M#	R.A.(2000)Dec..	Mag.	Mag.*	Size	Type	Con
IC 4776		18h45.9m −33°21′	11.0	—	8″x6″	IIa	Sgr
Humason 2-1		18h49.8m +20°50′	11.6p	13.3	3″	?	Her
NGC 6720	M57	18h53.6m +33°01′	8.8	15.0	85″x62″	IV+III	Lyr
IC 1295		18h54.6m −08°50′	13.5	15.0p	120″x90″	IIIb+II	Sct
Hubble 7		18h55.3m −32°16′	10.9	—	4″	II	Sgr
NGC 6741		19h02.6m −00°27′	9.9p	14.7	9″x7″	IV	Aql
Hubble 8		19h05.3m −33°09′	13.4	—	5″	II	Sgr
NGC 6751		19h05.9m −05°59′	12.2p	13.0p	18″	III	Aql
NGC 6765		19h11.1m +30°33′	—	—	38″	V	Lyr
NGC 6772		19h14.6m −02°42′	14.2p	18.7p	75″x50″	IIIb+II	Aql
IC 4846		19h15.7m −09°00′	12.7	—	2″	II	Aql
IC 1297		19h17.3m −39°36′	11.8p	—	8″x6″	—	CrA
NGC 6778		19h18.4m −01°35′	13.3p	15.0p	19″x13″	III+III	Aql
NGC 6781		19h18.4m +06°33′	10.3	16.3p	106″	IIIb+III	Aql
NGC 6790		19h23.2m +01°31′	10.3	10.5	9″x5″	II	Aql
NGC 6803		19h31.3m +10°03′	12.4p	15.2	5″	IIa	Aql
NGC 6804		19h31.6m +09°13′	11.0p	13.0p	63″x50″	IV+II	Aql
NGC 6807		19h34.6m +05°41′	13.8	19.3	2″	II	Aql
BD +30°3639		19h34.8m +30°31′	9.6p	10.1	3″	IV	Cyg
Merrill 1-1		19h39.2m +15°57′	12.6	—	2″	IV	Aql
Minkowski 1-74		19h42.3m +15°09′	—	—	2″	I	Aql
NGC 6818		19h43.9m −14°09′	10.0p	12.0	22″x15″	IV	Sgr
NGC 6826		19h44.9m +50°31′	8.7	10.6	27″x24″	IIIa+II	Cyg
NGC 6833		19h49.7m +48°58′	12.0	20.3	2″	II	Cyg
NGC 6842		19h55.0m +29°17′	13.6	16.0	55″	IIIb	Vul
NGC 6853	M27	19h59.6m +22°43′	7.3	12.0	480″x240″	III+II	Vul
NGC 6852		20h00.6m +01°42′	—	—	27″	IV	Aql
NGC 6857		20h01.8m +33°31′	11.4	13.3	40″	III+III	Cyg
NGC 6884		20h10.4m +46°28′	12.6	18.6	6″	IIb	Cyg
NGC 6879		20h10.5m +16°55′	13.0	15.2	8″	IIa	Sge
NGC 6881		20h10.8m +37°25′	14.3	—	5″	IIa+III	Cyg
NGC 6886		20h12.7m +19°59′	12.2p	15.7	6″	II+III	Sge
NGC 6891		20h15.2m +12°42′	11.4p	11.1p	12″	IIa+IIb	Del
NGC 6894		20h16.4m +30°34′	11.5p	17.5p	55″	IV+II	Cyg
IC 4997		20h20.2m +16°44′	11.4	13.7	2″	I	Sge
NGC 6905		20h22.4m +20°07′	10.4	14.2p	44″x37″	III+III	Del
NGC 7008		21h00.6m +54°33′	13.3p	13.3	86″x69″	III	Cyg
NGC 7009		21h04.2m −11°22′	8.0	11.9p	39″x30″	IV+VI	Aqr
NGC 7026		21h06.3m +47°51′	11.8p	14.2	28″x13″	IIIa	Cyg
NGC 7027		21h07.1m +42°14′	10.4	11.3	18″x11″	IIIa	Cyg
NGC 7048		21h14.2m +46°16′	11.3p	18.0p	60″x50″	IIIb	Cyg
IC 5117		21h32.5m +44°35′	13.3	—	2″	II	Cyg
Humason 2-1		21h33.1m +39°38′	12.7	—	5″	II	Cyg
NGC 7094		21h36.9m +12°47′	13.3	13.6	97″x90″	IV	Peg
NGC 7139		21h45.9m +63°39′	13.0p	18.0p	86″x70″	IIIb	Cep
IC 5148/5150		21h59.5m −39°23′	13.0	—	120″	IV	Gru
IC 5217		22h23.9m +50°57′	12.6p	15.5	8″x6″	II	Lac
NGC 7293		22h29.6m −20°48′	6.3	13.4	900″x720″	IV+III	Aqr
NGC 7354		22h40.4m +61°17′	12.9p	15.0	24″	IV+IIIb	Cep
IC 1454		22h42.6m +80°27′	12.6	18.6	34″	IV	Cep
Minkowski 1-80		22h56.3m +57°09′	14.0	—	8″	II	Cep
NGC 7662		23h25.9m +42°33′	8.6	12.7p	17″x14″	IV+III	And
Hubble 12		23h26.9m +58°11′	14.0	—	10″	—	Cas

All magnitudes are visual unless denoted as photographic (p) or blue (b).
Mag. = total magnitude of nebula; Mag.* = magnitude of central star
Types: I = stellar
IIa = oval, evenly bright, concentrated
IIb = same, but not concentrated
IIIa = oval, unevenly bright
IIIb = same, but with brighter edges
IV = ring-form
V = irregular
VI = anomalous

Martin Germano

M76 8-inch f/10 SCT
70 min., 103a-F

Lee Coombs

NGC 7662 10-inch f/5 Newtonian
5 min., 103a-O

Martin Germano

NGC 6543 8-inch f/10 SCT
5 min., 103a-F

Wil Tirion's *Sky Atlas 2000.0*, which plots dozens of planetary nebulae and is sufficiently large and detailed to star-hop with. The table on the opposite page provides data on 123 planetary nebulae north of −40° declination — this is a pretty complete listing of planetaries in the northern sky within the reach of amateur instruments. Most of these are plotted (if not labeled) on Tirion's atlas; you can plot the others yourself using the epoch 2000.0 coordinates.

Something you should be aware of is that magnitudes for nebulae and their central stars are in a bad state of disarray. Good UBV photometry for most of these objects does not exist, so that the magnitudes for many planetaries are 1930-vintage visual estimates by the astronomer Boris Vorontsov-Velyaminov. These figures, which appear in the table, are probably good estimates, but shouldn't be relied on totally.

Once you find the nebula you've gone after, be sure to record your observation in some organized manner. I describe the full appearance of the field of view in detail, mention any distinctive features such as double stars in the field, and estimate the magnitude and angular diameter of the object together with the distance between the object and bright field stars. I've also found sketches of the objects to be immensely helpful. They are not as difficult as you might think, and furthermore, they provide an inexpensive graphic representation of your observations. (For more on the "how-to," see "Sketching Low Surface Brightness Objects" on page 30, this issue.)

Let's now look at a few objects from the table in more detail:

M27, the Dumbbell Nebula Bright and easy to find (though situated in an inconspicuous constellation), the Dumbbell is a favorite of summer and fall observers. To locate the Dumbbell, first identify the star Altair in Aquila, one of the Summer Triangle's three luminaries. Five degrees north of Altair lies Sagitta, the Arrow. Gamma (γ), the easternmost of Sagitta's five stars, is our next reference point. Locate it and sweep 3½° north; the Dumbbell should be in your eyepiece. Another method for finding M27's general location is to look a third of the way from Altair to Deneb.

Use generally low powers as you search for M27 — or any other nebula, for that matter. Once found, M27 shows up best with medium power — say 15x per inch of aperture. (It is also visible in binoculars.) A 6-incher may reveal the central star on a very good night and 8-inches' or more will do it for sure. Although it is relatively bright (8th magnitude), the Dumbbell spreads over enough sky to lower its surface brightness to the point where high magnifications will make the viewing difficult. You'll find it very easy to make out the hour-glass figure that gave rise to its nickname, even though its two ends are not equally bright.

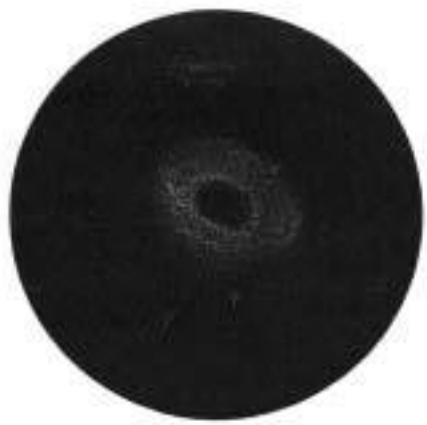
M57, the Ring Nebula Even easier to find than M27 is "the Ring." Positioned between two bright stars, Beta (β) and Gamma (γ) Lyrae, at the southern end of the figure, the Ring Nebula lies almost on a straight line and a little more than halfway from Gamma toward Beta. As with M27, searching with low powers is a must, for there are many stars in this part of the sky.

When found, the Ring looks just like its namesake, though in a small instrument (4-incher or less), you may not be able to see the dark hole in the center except by averted vision. The central star itself awaits superb transparency and at least a 16-inch scope. Because of its compactness relative to the Dumbbell, the 9th magnitude Ring can benefit from more

M76 3-inch f/27 SCT
67x

sketch by F. Michael Witkoski

NGC 7662 12.5-inch f/5 Newtonian
200x



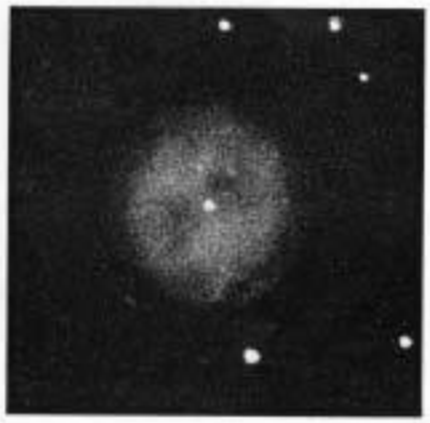
sketch by Chuck Coates

NGC 6543 6-inch f/8 Newtonian
150x

sketch by Glenn Chaple

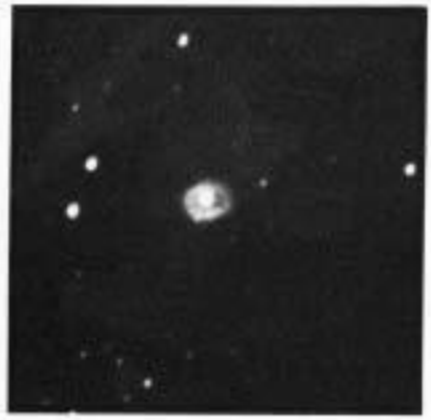
Martin Germano

NGC 2392 8-inch f/10 SCT
6 min., 103a-F



Alfred Lilge

M97 12.5 f/8 Newtonian
75 min., 103a-O



Martin Germano

NGC 3132 8-inch f/10 SCT
15 min., 103a-F

magnification — as much as several hundred times if seeing conditions are good and your scope has sufficient aperture.

NGC 6826, the Blinking Planetary About 25 arcseconds in diameter, this nebula is small compared to the Ring or the Dumbbell, but its surface brightness is much higher and its central star more easily seen. Its name comes from the fact that it appears to blink on and off as you shift your gaze from the edge of the telescope's field of view to the nebula itself. When you look at the edge of the field you'll see the nebula, which is faint and is detected by averted vision. But when you look directly at the nebula, it disappears and you see the central star! Delta (δ) Cygni lies a handy 5½° south of 6826 and makes an excellent guidepost.

NGC 7009, the Saturn Nebula The Saturn Nebula is among the easiest planetary nebulae to locate, as it lies less than 2° west of the naked-eye star Nu (ν) Aquarii. At magnitude 8.0 it is brighter, overall, than the Ring Nebula and, since it is smaller in area, it has a greater surface brightness.

The nickname "Saturn Nebula" dates from about 1850 and comes from its appearance in the 72-inch telescope of the Earl of Rosse. A good photo shows its resemblance to Saturn: the nebula has two symmetrical lobes extending from the edge of its disk. Unfortunately, small telescopes simply can't show this: the Earl had a 72-incher — and you don't. But the nebula itself is not hard to spot in a small telescope by the unmistakable way it looks like an blue-green star seen out of focus.

NGC 7293, the Helix Nebula In Aquarius, 22° southeast of the Saturn Nebula, is the Helix (or Helical) Nebula, the largest and brightest planetary nebula in the sky but also one of the most difficult to see. This planetary's integrated magnitude is 6.5, which puts it first in total brightness. But since it measures 900 x 720 arcseconds — roughly half the diameter of the Moon — all that magnitude is spread out over an immense area and so the Helix has a very low surface brightness. It is so dim that even William Herschel failed to spot it. For seeing this object, a wide-field, low-power eyepiece is crucial since it'll simply disappear under higher magnification.

Visually, you ought to be satisfied just to find and positively identify the nebula; any haze wipes it out totally. Through a telescope or binoculars it resembles a large, ghostly wreath. Photos show a twisted structure which suggests its helix name. Unlike the Saturn Nebula, you'll not see any color in the Helix — it's just too dim. Try using averted vision; the 13th magnitude central star is difficult at best with small scopes, but under good conditions, a 6-incher may just show it.

M76, the Little Dumbbell Nebula To locate M76, you need only find the 4th magnitude star Phi (ϕ) Persei and sweep your telescope about a degree northwest. This object, which has two distinct parts, is not an ordinary planetary since the parts have separate NGC designations: 650 and 651. M76 is bright enough to take magnification pretty well, and its resemblance in the eyepiece to M27 is obvious. It is not a uniformly bright patch of haze, however. It appears to have knots or streaks of lighter material here and there in it.

NGC 7662 A short hop into neighboring Andromeda will show you NGC 7662, a small bright planetary. At magnitude 8.5 it is among the easiest of the planetary nebulae to detect, but don't expect to see any detail or its central star. Look for a blue-green out-of-focus star. Through small instruments 7662 resembles the Saturn Nebula,

NGC 2392 4.25-inch f/10 Newtonian
276x

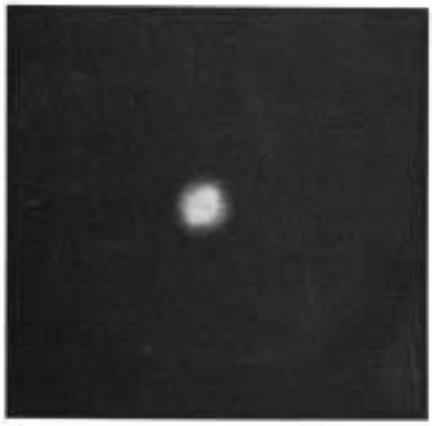
sketch by Jim Garasich

M97 8-inch f/10 SCT
78x

sketch by Chris Quinnert

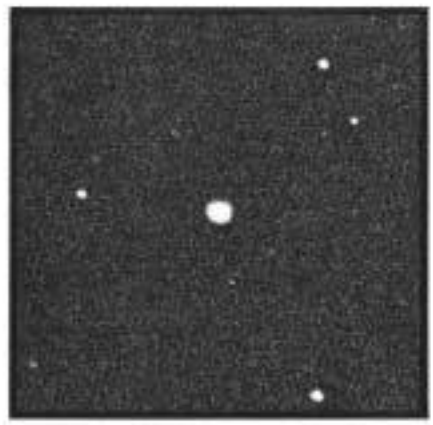
NGC 3132 8-inch f/10 SCT
170x

sketch by David J. Eicher



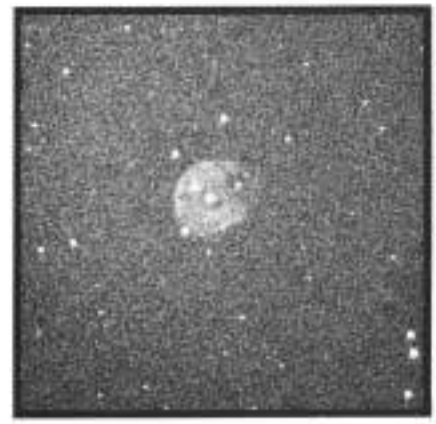
Howard Zeh

NGC 3242 14-inch f/10.5 SCT
1 min., 103a-E



Martin Germano

NGC 6210 8-inch f/10 SCT
6 min., 103a-F



Lee Coombs

NGC 246 10-inch f/5 Newtonian
15 min., 103a-E

though long exposure photographs reveal many differences. Search a degree south-southwest of the naked-eye star 13 Andromedae to locate NGC 7662.

NGC 6543 Another planetary for small scopes is NGC 6543 in Draco. Its declination is high enough to keep it visible year-round from most of the northern hemisphere. At magnitude 8.6 and with a relatively small size, this specimen is one of the brightest per unit surface area and most colorfully conspicuous of the planetary nebulae.

NGC 2392, the Eskimo Nebula Located in Gemini about halfway between M44 and M35, NGC 2392 shines at magnitude 8.0 and, although a bit compact at 40 arcseconds, it is large enough that even low magnifications will show it as non-stellar. Its name comes from its appearance in photographs, but you'll be able to see the central star surrounded by nebula. Unlike most other planetaries, many of which are dimmer or more spread out, 2392 can withstand a slight amount of moonlight or submarginal skies.

M97, the Owl Nebula Discovered in 1781 by Pierre Mechain, M97 is large and distinctive. The name comes from the Earl of Rosse, who first observed two dark patches reminiscent of eyes which show in photographs. With a small telescope, you'll have a lot of difficulty seeing the eyes; the object will most likely appear very uniform. Try using a 12-inch scope on a very dark night; the two small round patches may show themselves. The Owl lies about three degrees southeast of Beta (β) UMa.

NGC 3132, the Eight-Burst Nebula At declination $-40°$ 25′ in the constellation Vela lies a planetary that's a close runner-up to the Ring and Dumbbell. Called the Eight-Burst Nebula for its complex appearance in photographs, NGC 3132 has a prominent star within the nebula, but this is probably only a chance superposition. The actual central star is a dimmer object near the bright one.

NGC 3242, the Ghost of Jupiter Another southern planetary for small scope users is NGC 3242. The best pointer star is Mu (μ) Hydrae, lying just 2° to the north. Although not quite as fine a sight as 3132, this planetary compares favorably with the Saturn Nebula, NGC 7662, and NGC 6543.

NGC 6210 Found in Hercules, NGC 6210 has a magnitude of 9.7, a size of 20x16 seconds of arc, and it has no conspicuous central star. It is bright and compact and thus displays the typical blue-green color of a planetary. Zeta (ζ) Herculis lies about 8° north of NGC 6210

NGC 246 A large planetary in Cetus, NGC 246 is located 6° north and less than a degree east of Beta (β) Ceti, its immediate neighborhood has identified by four very dim stars. A good night will reveal the sprawling nebula, which demands only the most transparent nights if you want to see it.

* * * * *

Planetary nebulae are one of the most intriguing and unique objects you can point your telescope at. The varied shapes, sizes, colors, and brightnesses of these ghostly puffballs will keep you thinking of the magnificient view you've had of the Ring, the Dumbbell, the Helix, and the Owl for many days after you experience them "live."

Dave Kratz is currently working on his PhD in mechanical engineering at SUNY in Stony Brook, N.Y. He is an accomplished amateur astronomer, co-author of the "Ursa Major" observing project, and holds a Master's degree in astrophysics.

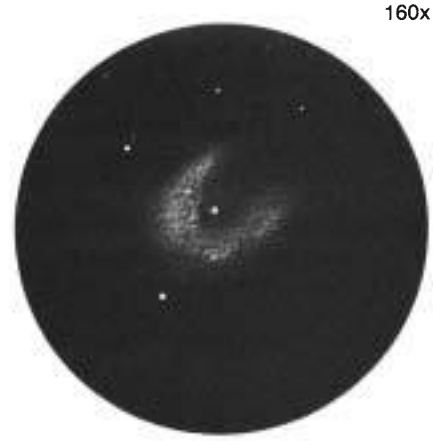
NGC 3242 10-inch f/6 Newtonian
136x

sketch by Dan Troiani

NGC 6210 6-inch f/8 Newtonian
120

sketch by Randy Lutz

NGC 246 12.5 f/5 Newtonian
160x



sketch by Chuck Coates

What Makes A Planetary Nebula?

by Francis Reddy

Both amateur and professional astronomers find planetary nebulae intriguing. Amateur astronomers are attracted by their delicate beauty, while the professional relishes the opportunity to examine the final stages in the life of a star of moderate mass. But this "last flash of glory" constitutes a remarkably brief phase of stellar evolution, since planetary nebulae typically disperse into the void less than 20,000 years after they form. Eventually, their material will become the fuel for future generations of stars.

What makes a planetary? Ideas about their origin have embraced both extremes of stellar evolution. At one time, astronomers believed that stellar explosions called supernovae were responsible. A violent explosion could throw off much of a star's material, they reasoned, and hurl it outward at high velocity to form an expanding shell of gas. By the late 1950s, however, it became clear that supernovae are *too* powerful — their gaseous remnants expand a thousand times faster than any planetary nebula does. And at the other extreme, one Soviet astronomer argued as recently as 1969 that "planetary nebulae are not formed from any existing stars in the Galaxy, but rather from pre-stellar objects which evolve into proper stars producing planetary nebulae as a byproduct." He believed that the glowing spheres of gas were the remnants of star birth, not the prelude to stellar death.

Astronomers have catalogued over 1,000 planetary nebulae. The typical specimen is a shell of gas with less than half the mass of our Sun. A small fraction of this gas absorbs energetic radiation from the central star and re-emits it as visible light through the process of fluorescence. The central sun of a planetary nebula is an extremely hot, compact object called a white dwarf. A white dwarf is a star which holds about the same mass as our Sun, but is compressed to the size of the Earth. The dwarf is the freshly exposed core of a red-giant star, and the rarefied gas surrounding it is a remnant of the giant's outer envelope. This gas expands away from the star at a few tens of kilometers per second. All stars with masses less than about five times that of our Sun will pass, fleetingly, through this phase.

Several lines of evidence point to red-giant stars as the creators of planetary nebulae. First, calculations indicate that whenever a star forms a white dwarf on the inside, its outside *looks* like a red giant: low surface temperature, high luminosity, great size. Second, the tiny white dwarf at a planetary's center probably did not expel the gaseous shell that surrounds it. The surface gravity of a white dwarf is extremely high and only some brief, very energetic outburst could force it to shed material — which is belied by the relatively slow expansion rates of the nebulae. It's more likely that the material was ejected when the star had a much lower surface gravity — in its bloated red-giant stage, for example. Third, we know that red-giant stars undergo events that could easily initiate the ejection of material.

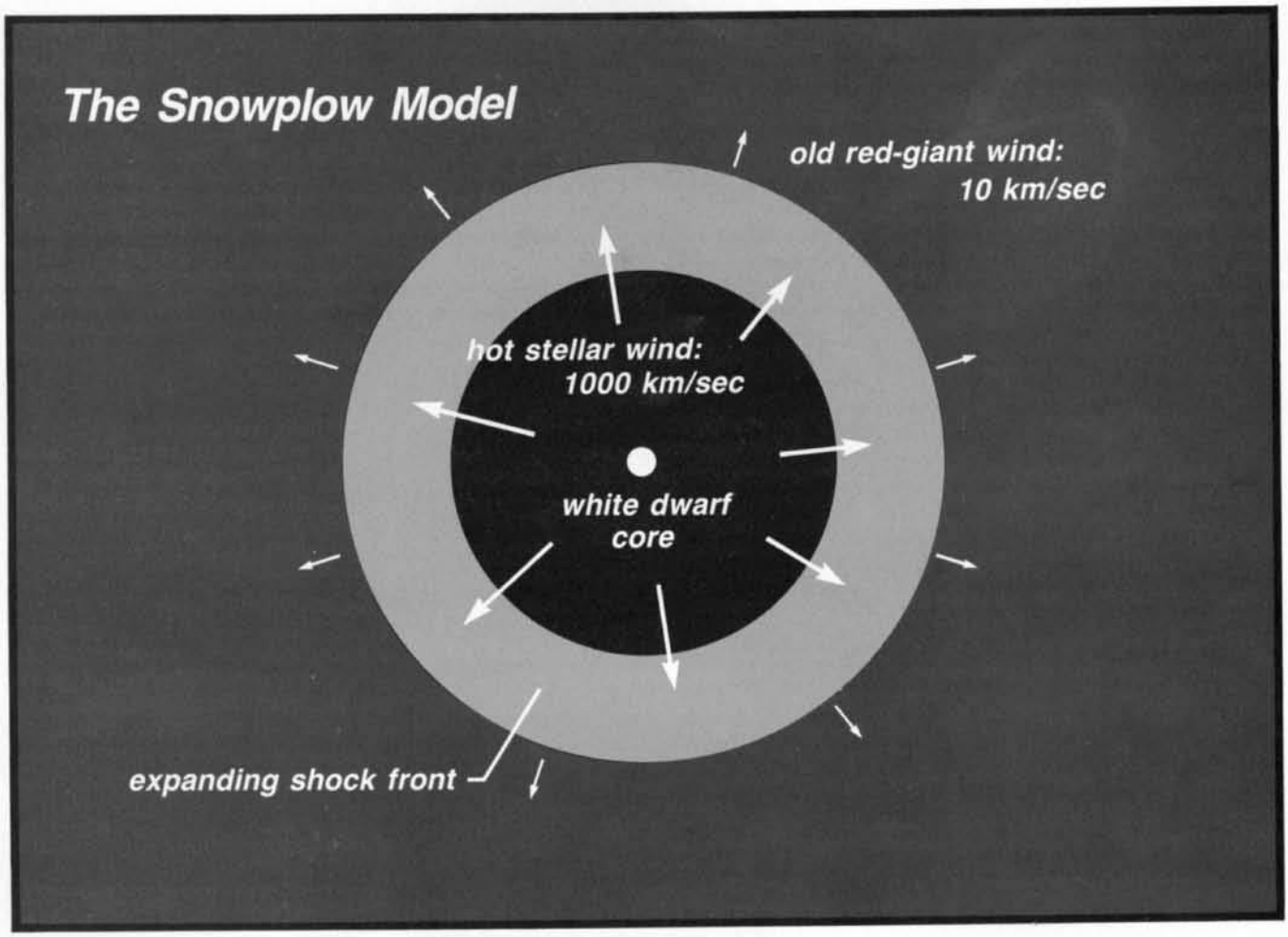
Most astrophysicists think that the formation of a planetary nebula is an inevitable evolutionary phase for low-mass, Sun-like stars. Why? The standard scenario goes like this: When a star uses up all the hydrogen fuel in its core, it must change to a different fuel. Our Sun now obtains its energy through hydrogen fusion: smashing together hydrogen nuclei to create helium nuclei and releasing energy. As a star ages, this process leaves an "ash" of helium in the core. When the star's core runs out of hydrogen, it uses the abundant helium as fuel. This switch to a new energy source leads to dramatic changes in the star's physical characteristics. The Sun, for example, will be about 100 times larger and brighter at the height of its career as a red giant, engulfing the planet Mercury. Helium fusion begins with a violent event called the "helium flash," which sends shockwaves throughout the star that could trigger an abrupt ejection of matter. As the star ages, it will begin to pulsate and may undergo further outbursts, possibly ejecting material.

Straightforward as this picture seems, some astronomers feel uncomfortable relying on sudden, catastrophic processes like stellar outbursts. While instabilities in a helium-burning red giant undoubtedly can create expanding shells of gas, is that the only way? Couldn't these stars also take a less violent route to the planetary nebula phase?

Most stars, including our Sun, blow a steady stream of material into space. The Sun's flow, called the "solar wind," consists of electrically-charged particles. This lost matter doesn't amount to much — if collected over one trillion (10^{12}) years, it would make up less than one-tenth of the Sun's total mass. But the solar wind hasn't always been this insubstantial, nor will it remain so. It was far stronger eons ago, when the Sun was new, and it will intensify again as our star ages. A star's size radically increases when it bloats into a red giant, so its surface gravity correspondingly decreases. The star contains the same amount of mass, but spread throughout a far greater volume. The lower surface gravity of red giants makes it easier for material to escape from their surfaces and so the stellar wind of a red giant ought to eject much more mass than that of our Sun.

The most intense red giant winds blow away a solar mass of material every 100,000 years. Betelgeuse, the bright star in Orion's upper left corner,

The Helix Nebula (NGC 7293) in Aquarius resembles two off-center smoke rings that are entwined — hence its nickname. Surrounding the bright ring is an outlying shell of older and much dimmer gas. Kitt Peak National Observatory photo.



In the "snowplow" model (above), the intense stellar wind from the hot core of the star collides violently with the gently-outflowing wind from the red-giant phase of the star's evolution. At the interface, the gas is highly compressed and glows brightly. In an alternate model (right), one member of a close binary system (orbital period less than 10 years) evolves into a red giant. As its atmosphere extends to encompass the companion, material from the red giant is ejected to become the planetary nebula.

presently loses matter at the more leisurely rate of about one solar mass every million years. The mass of a typical planetary nebula — around one-tenth that of the Sun — is minuscule compared to the amount of material removed by these stellar winds. Radio astronomers have detected faint extended halos of stellar-wind-driven material around several red giants. The halo that envelopes Betelgeuse, for example, extends out to 1.5 arcminutes from the star. It seems reasonable to suggest that, if planetary nebulae evolve from red giants, then such faint, low-density halos should also surround them. In fact, astronomers have found halos around several planetaries.

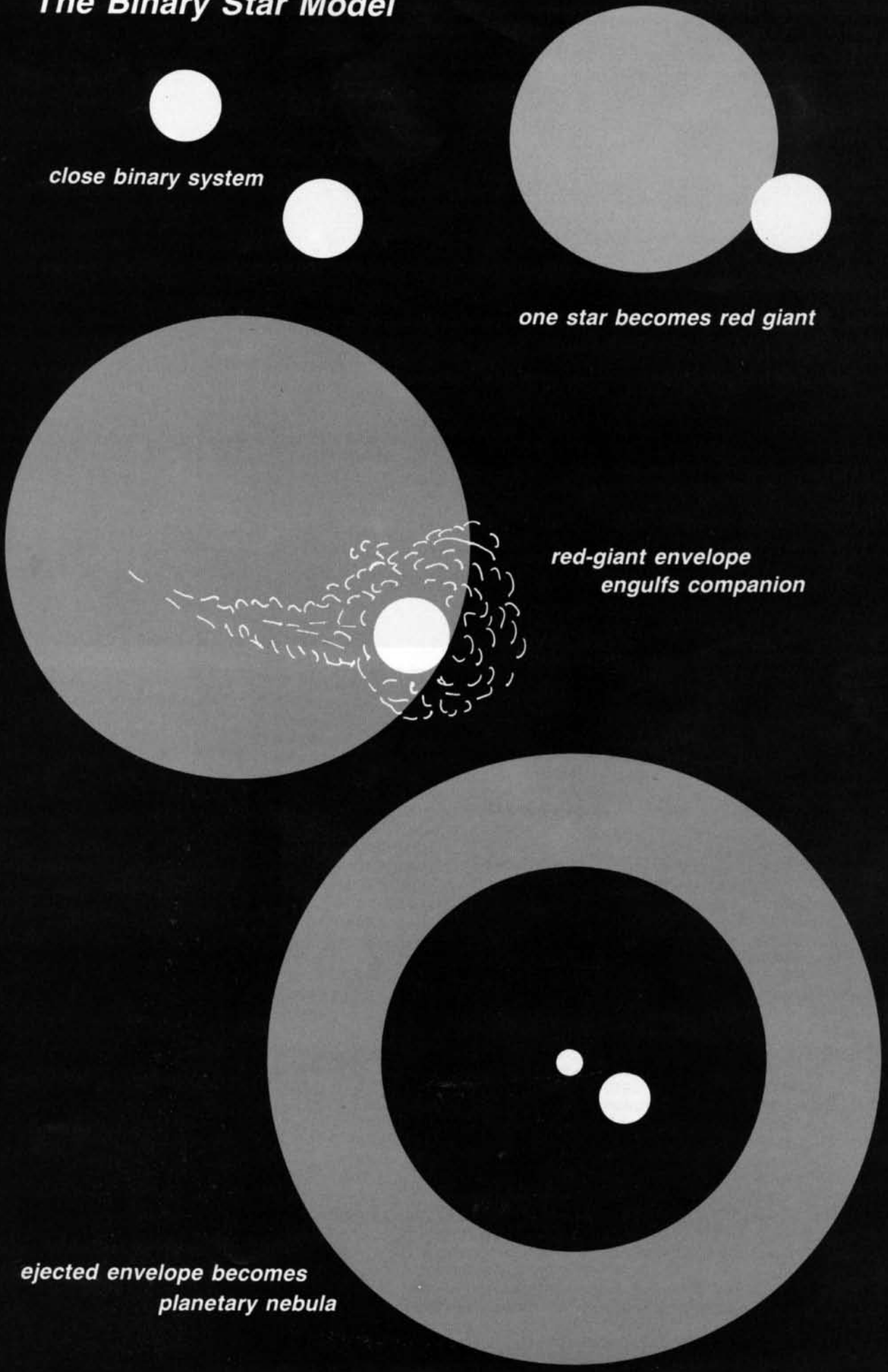
In 1978, a group of Canadian astronomers came up with a possible relationship between the low-surface-brightness halo and the bright, ionized component of a planetary nebula. Since the mass of a planetary nebula is so small to begin with, it could be created by rearranging the material that makes up the wind-ejected halo. The researchers, led by Sun Kwok of the Herzberg Institute of Astrophysics, suggested that a temporary gale-force stellar wind could "snowplow" material from the inner halo into an ionized shell.

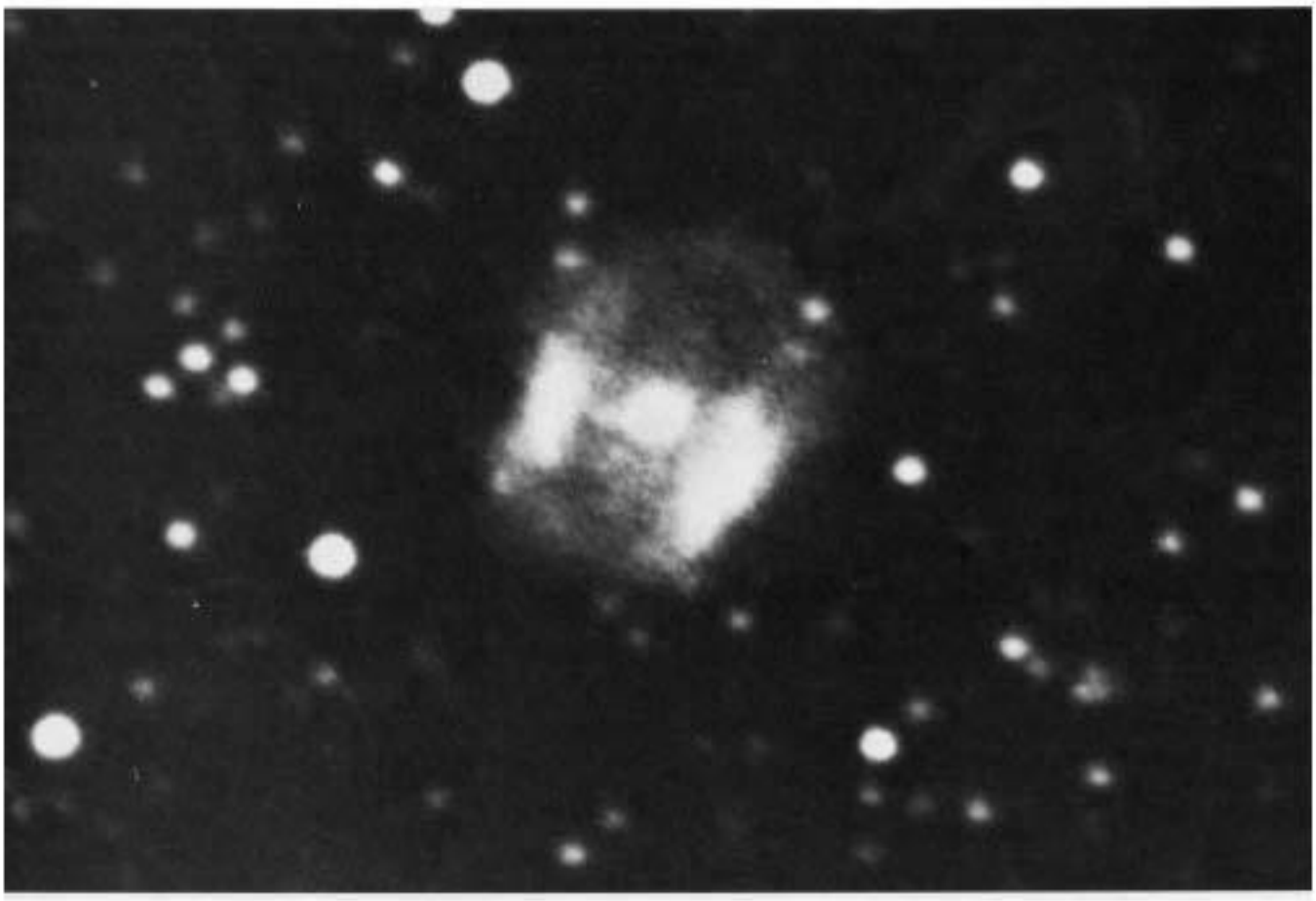
A red giant consists of a hot, dense core (a proto-white dwarf) and a very cool, tenuous envelope. Kwok's group argued that a red giant's wind continues to blow until it exposes the core. Initially, matter flows from the star at about 10 kilometers per second, but as the star's envelope peels away and bares deeper and hotter layers, the velocity of the wind increases. By the time mass-loss uncovers the hot core, the wind is blowing at around 1,000 kilometers per second. This vigorous new "superwind" slams into the gas and dust ejected previously by the slower wind and pushes hard on the material as it streams outward. Gas and dust pile up at the interface between the two winds and this dense region emits visible light. The superwind/halo interface forms a thick shell — which to us appears ring-shaped — because of the strong pressures on either side of it. After a few millennia, Kwok determined, the bubble produced by a superwind would match the size, density, and expansion velocity typical of a planetary nebula.

Red giants probably expel their envelopes by a variety of mechanisms. While the "snowplow" model has much to recommend it, astronomers cannot determine its importance without first examining in detail the complex interactions between superwind and halo. For the moment, at least, Kwok's colliding wind model offers an alternative mechanism for making planetaries; astronomers may not have to resort to stellar violence. But with this realization another question arises. If red giants can form planetaries through more than one mechanism, could the nebulae be formed by more than one type of star? Or, to put it another way, are planetary nebulae a homogeneous group of objects?

Some of the most energetic stellar phenomena in the Galaxy occur when stars orbit very close to one another. When observatory satellites revealed the X-ray sky in the 1970s, astronomers found stars that emit energetic bursts of X-rays every few seconds (X-ray bursters) and stars that shoot out broad intense beams of radiation (X-ray pulsars). They also found that one mechanism explained all of these systems: matter flowing from a run-of-the-mill Sun-like star falls onto a dense

The Binary Star Model





Abell 41 is an oddly-shaped planetary in Serpens that surrounds a binary star system, and is a living example of the theory sketched on page 19. Photo from Howard Bond, Louisiana State University.

companion (such as a white dwarf or a neutron star), producing X-rays in the process.

Low-mass X-ray binaries have a lot in common with the so-called cataclysmic binaries, which are responsible for all nova outbursts. Both systems are very explosive, share the same range of orbital periods, and can be explained by the same mechanism. For cataclysmic binaries, however, a white dwarf must replace the neutron star as the dense companion. Astronomers could account for the behavior of these systems by the mid-1970s, but they were at a loss to describe how stars could get so close — one or two Suns would barely fit between them.

What has all this to do with planetary nebulae? As we've seen, astronomers believe that white dwarfs form in the cores of red-giant stars — which are typically much larger than many close binary systems. In 1976, Princeton University astronomer Bohdan Paczynski suggested that, for a brief period, one star actually *penetrates* its companion. He called this configuration a "common envelope" binary, and it works like this:

Start with a pair of normal stars orbiting one another in a decade or less. One star bloats into a red giant and develops a white dwarf in its core. As the giant expands, it becomes so huge that it actually engulfs its companion. Even though the red giant's envelope is very tenuous — it has been called a "red-hot vacuum" — it still creates friction which produces drag. The separation of the two stars decreases as the secondary loses its angular momentum and spirals in toward the giant's white-dwarf core. Since nature always conserves angular momentum, it must go someplace. The momentum lost by the spiraling secondary is transferred to the red giant's tenuous envelope. "Eventually, the envelope may be ejected," says Albert Grauer, an astronomer at the University of Arkansas, "producing a planetary nebula whose nucleus is a moderately close binary containing a hot, degenerate primary [the white dwarf] and a cool, Main-Sequence secondary."

While the common-envelope phase is remarkably brief — only about 1000 years — the planetary nebula stage lasts just as long as a planetary produced by a solitary star. So far, four of these close-binary central stars have been identified. The first such object, UU Sagittae, was found in the center of planetary nebula Abell 63 by Howard Bond of Louisiana State University. That discovery prompted Bond and Grauer to search for more close binary stars in planetary nebulae in an attempt to provide further support for the common-envelope scenario. Their most remarkable find is Abell 41, whose central suns orbit one another in just under three hours! After the nebula dissipates, these systems will continue to spiral closer together, but at the much slower rate of normal binaries. As their periods decrease to two hours, the stars will start transferring matter between them and begin the explosive variability typical of cataclysmic binaries.

As with Sun Kwok's colliding wind model, the common envelope scenario leads to the creation of a planetary nebula without the violence of a stellar outburst. But this model, however, guarantees violent events in the future. The success of Paczynski's common envelope model in predicting the existence of these objects has led him to suggest recently that most or even all planetaries may be ejected by binary central stars — but there is not yet enough evidence to support this claim.

Tracing the origins of planetary nebulae has taken us from the simple concept of a stellar "burp" to bizarre binary systems where stars temporarily engulf their companions. It's probably safe to say that any final picture will include elements of all the models we've discussed — and perhaps some we haven't even thought of yet!

DSM Reviews

Atlas of Deep-Sky Splendors, 4th edition
Hans Vehrenberg
Co-published by Sky Publishing Corp., Cambridge University Press, and Treugesell-Verlag, 1983
242 pages, $39.95

The Cambridge Deep-Sky Album
Celestial photographs by Jack Newton and text by Philip Teece
Co-published by Cambridge University Press and AstroMedia Corp., 1983
128 pages, $19.95

Both these books have appeared at the same time and indirectly from the same publisher. Observers should rejoice that there are now several choices among "picture books" showing their favorite deep-sky objects. While others, like Tim Ferris' *Galaxies*, can be enjoyed by anyone, these two new books are aimed principally at the observing amateur.

Both feature a series of photographs of galaxies, clusters, and nebulae with captions covering astrophysical data and other information about each object. Vehrenberg's photos were taken mostly with fast short-focus Schmidt cameras, while Newton used his 16-inch f/5 Newtonian telescope. In addition, the *Deep-Sky Album* is introduced by a brief description of Mr. Newton's telescope and home-built cold-camera systems. The Vehrenberg *Atlas* has a more extensive text. including historical treatises on Messier, Lacaille, and Schmidt. A detailed discussion of each type of deep-sky object includes information about what astronomers try to learn about them.

The two volumes are distinctly different. Vehrenberg has the certain advantage of having produced the fourth edition of his book, and thus has had the opportunity to work out the bugs. Indeed, Newton, too, has had a trial run with his *Deep-Sky Album* from several years ago.

Most of the photographs in the Vehrenberg *Atlas* are black and white, and they are without exception excellent. Most of the plates have an image scale of 1 arcminute per millimeter, close to that of the Palomar Sky Survey charts. Vehrenberg's book is like a set of POSS prints of your favorite objects and areas of the sky. It is even better in the sense that many spectacular southern Milky Way fields are included. In the section of the book around 12h RA (the objects are organized by increasing right ascension) there is a wonderful contrast between relatively barren fields of northern galaxies on some pages interspersed with Milky Way fields in Carina, Crux, and Centaurus saturated with stars, clusters, and nebulae. On most plates north is up and east to the left, as we see on the sky. A few fields are tilted so as to include two widely separated objects at the nominal scale of 1′/mm. In all cases the border around the photos is marked with coordinate index lines, so there is never any doubt about the orientation of the field. This feature is a helpful you for use at the telescope, since one can readily compare an eyepiece field of a given size to the photo. When the principal object in a field is small — as are many of the galaxies — the facing page often contains a closeup view taken with a large observatory instrument. (Will those over-published Hubble Atlas shots ever disappear from the literature?)

There are a couple of dozen color photographs in the book. Some were taken on Ektachrome or Fujichrome; others were made using the three-color separation method which combines filtered black-and-white shots into a color composite. In theory the tri-color procedure is more faithful to the true colors of a nebula or galaxy, but as reproduced in the book, I much prefer the subdued tones of the color transparency films to the brilliant tri-color plates, which sometimes verge on the garish. Nearly all of the color plates are nevertheless well printed. The stars have been masked in the screening process so that no black ink appears in them and their images are crisp as long as the screens are in register.

This careful color-separation work clearly was not done for Newton and Teece's *Deep-Sky Album*. This is a much smaller and thinner book containing only color photographs. Unfortunately none of the photos matches the quality of the color plates typical of the Vehrenberg book. Some of the plates have varying background tones caused by saturation of the screen during printing, and sharp bands of ink occasionally cross the image. The sky background often varies in hue and intensity from page to page: often a pleasing dark "Ektachrome" blue faces a bizarre magenta cast. Many of the plates are misregistered, leading to a general muddiness. The photo of NGC 6946, for example, is covered by double stars: all yellow and purple, of the same separation and position angle, and differing only in brightness.

Readers of *Astronomy* and *Sky & Telescope* know that Mr. Newton's astrophotography sets a high standard. Some of the plates in this book have already appeared in these magazines, and they're excellent. Clearly the blame for the poor color separations and the shoddy press work lies not with Newton but with the publisher and its printers.

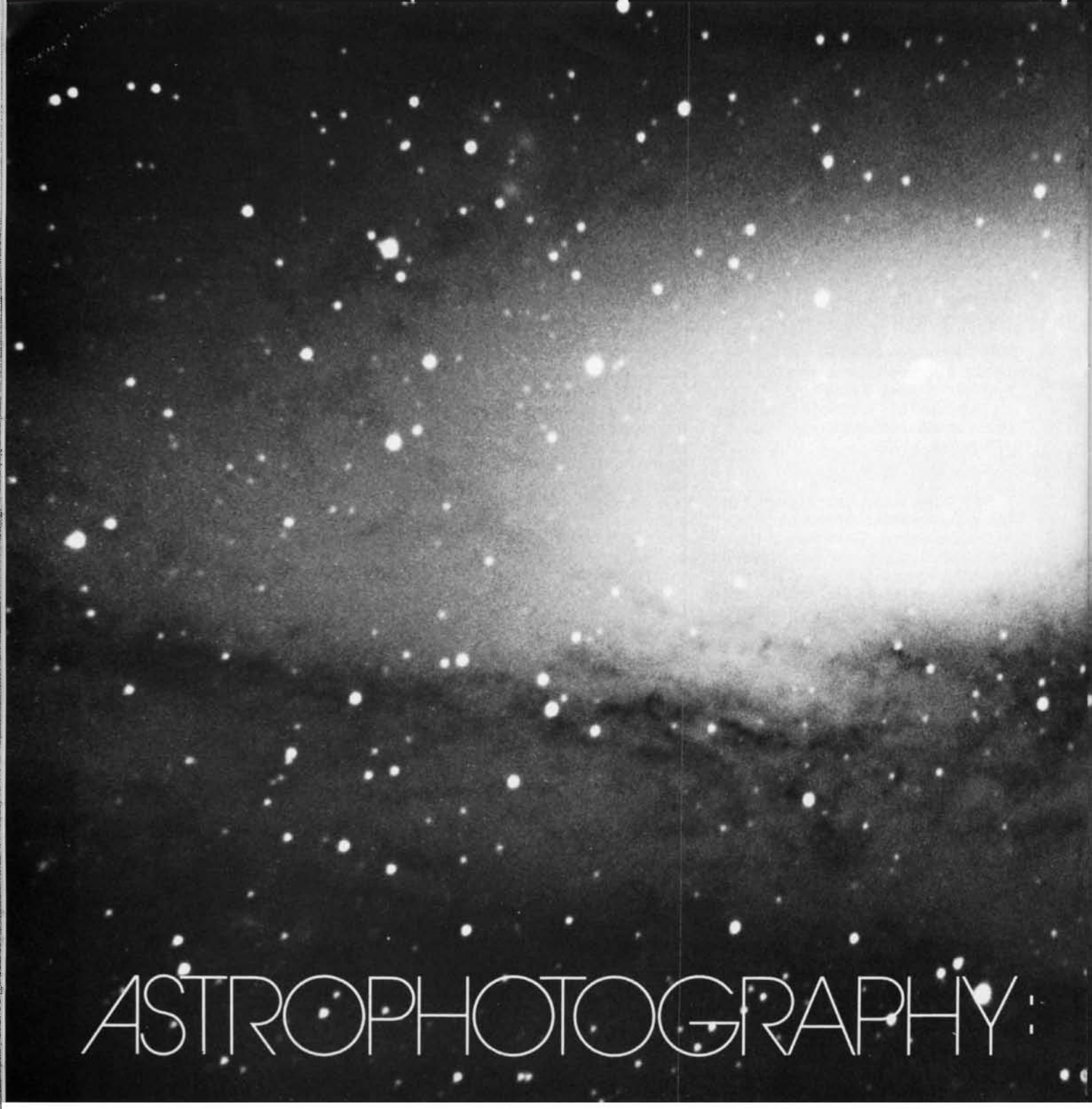
There is another correctable problem with the book. The authors should have taken more care with the little blocks which accompany most of the photographs to show cardinal directions and key prominent features in them. I found several that are rotated 180° from the correct orientation: thus both east/west and north/south are flipped with respect to the photo. Several more are reversed only in one direction, while still more are skewed by 10° to 30°. The Lagoon Nebula photo shows north at lower left, but its field diagram has the usual north-up/east-left arrangement. Paradoxically, the orientation of features in this block matches the photo correctly!

One advantage the *Deep-Sky Album* has over the *Atlas of Deep-Sky Splendors* is that the image scale for most of the photos is about three times greater — typically 20″ to 22″/mm, though a few are at about 30″/mm. This permits Newton to go for many small objects that are lost to Vehrenberg's Schmidt cameras.

I was not especially impressed by the texts of either book. Vehrenberg writes somewhat more smoothly than does Teece, but the difference isn't great. By and large the information is good, but there are several instances of outdated results and confusing discussions.

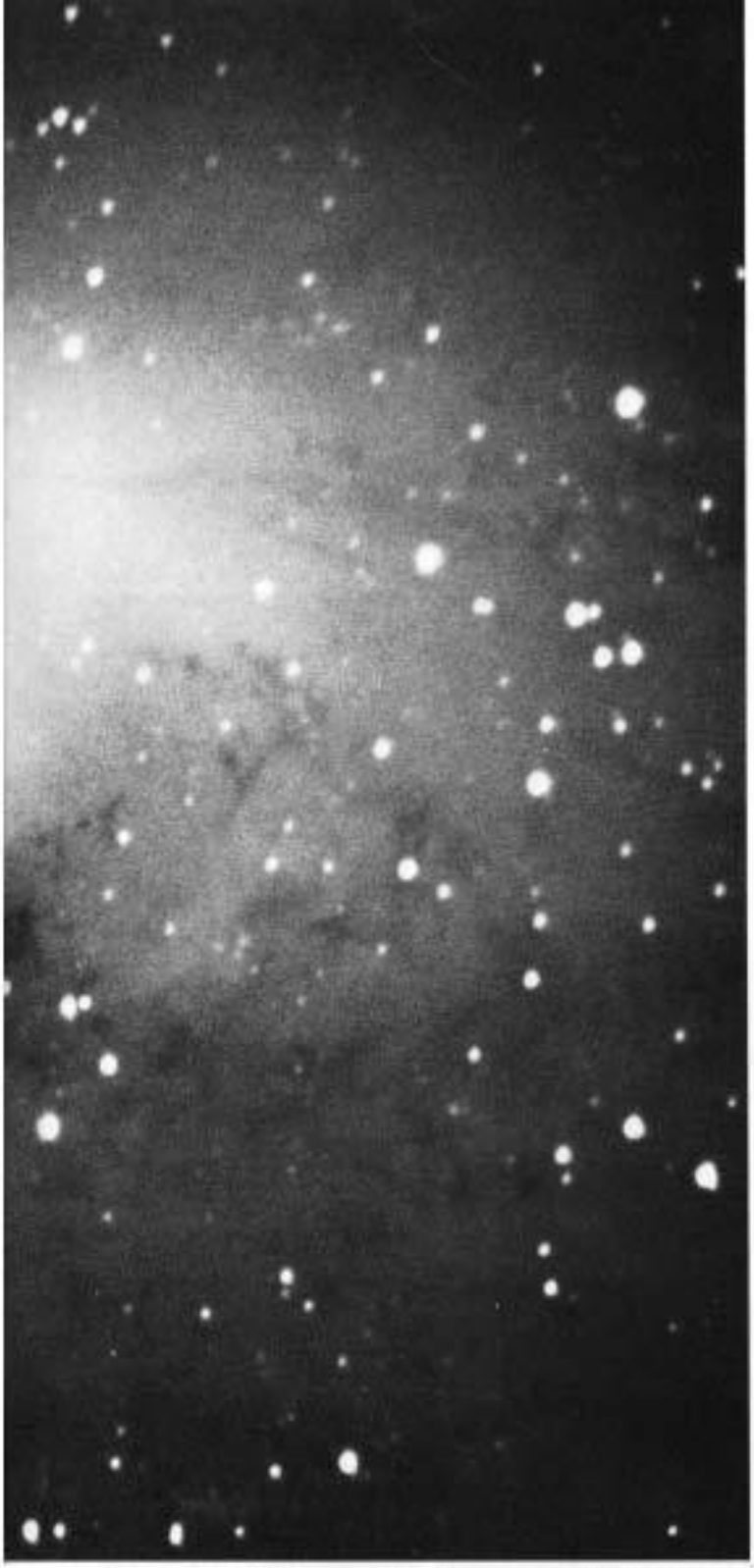
These books show the state of the art of traditional amateur astrophotography. It is easy to recommend Vehrenberg's book; it is the lush and expensive standard against which other books like it are compared. I can also recommend the half-sized, half-priced volume by Newton and Teece, but without enthusiasm, bearing in mind the shortcomings mentioned above. According to the authors, a second printing with improved color reproduction is in the works, and copies of this second impression may be available by the time you read this.

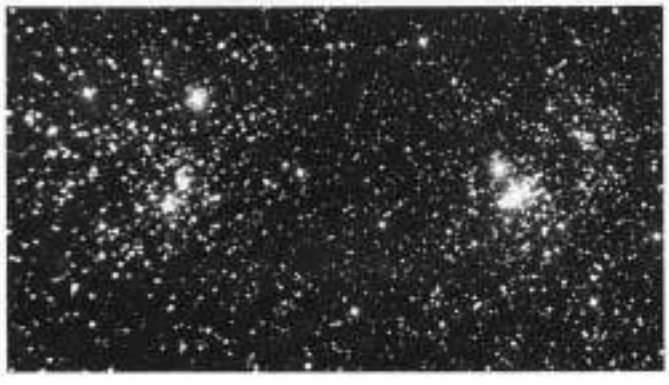
Brian Skiff
421 West Aspen
Flagstaff, AZ 86001



Shooting Through the Scope

by David Healy





Left: **Paul Roques made this closeup of the core of M31. It is an 85-minute exposure on hypersensitized TP 2415 emulsion, shot with a 10-inch f/10 SCT. The photo has southeast at top, southwest at left. *Below*: This 13-minute exposure by Jack Newton — made with 103a-F emulsion and a 12.5-inch f/5 Newtonian — shows NGC 884 (left) and NGC 869 (right). This and other photos in the article — unless otherwise noted — have north at top, east at left.**

My series on photographing objects beyond the solar system began in DEEP SKY 4, wherein I described how to polar-align a mounting for astrophotography. In the last issue we looked at how to take photographs using standard, wide-angle, and telephoto lenses piggybacked on your telescope. This article covers some of the rewards and pitfalls of a more demanding deep-sky photo method — taking pictures through the telescope. This turns your telescope into a giant camera, whose long focal length and high magnification provide "closeups" of star clusters, nebulae, and galaxies. But in so doing you increase exposure times to 10 to 120 minutes, and also reduce the tolerance for all kinds of mistakes: guiding errors, focusing problems, wind, etc.

Many of these photographic blunders were evident in my first deep-sky photograph, a shockingly bad shot of the Andromeda Galaxy. As a matter of fact, the mistakes in this photo were so comprehensive as to be an outline of what *not* to do: (1) the telescope was not polar-aligned, (2) the exposure was unguided, (3) the camera was out-of-focus, (4) I used the wrong film, (5) the focal ratio was too high, (6) the telescope's corrector plate dewed up, (7) the exposure time was too short, (8) the galaxy was too big to fit into the telescope's field-of-view, and (9) I was shooting color film from a light-polluted area. The first two articles in this series covered blunders (1), (2), and (8). This time we'll tackle blunders (3), (5), and (6).

Using Setting Circles

But first, what about *finding* the object you want to photograph? Bad as my first photo was, the blurry smudge on the film *was* the nucleus of the Andromeda Galaxy. But what about finding, say, a galaxy too faint for the eye or even the finderscope? One way, of course, is star-hopping: using a star atlas to move by steps from a naked eye star to the desired object. This is how most observers find objects. But a quicker method for photography, in my opinion, is using the telescope's setting circles. If the telescope is properly polar-aligned, then one can use the object's celestial latitude and longitude to bring it into the field-of-view of a long-focus eyepiece or camera finder, usually on the first attempt. Let's say, for example, that we want to find and photograph M57, the Ring Nebula in Lyra. The Ring, the best known planetary nebula, is a bit small to show in the average finderscope, but is easily locatable with setting circles.

The method starts with selecting a bright "locator" star — whose coordinates are known — in the same area of the sky as the object. For the Ring Nebula, the best locator star is Vega, which has a right ascension (its "longitude," or east/west coordinate) of 18h 36m and a declination (its "latitude," or north/south coordinate) of +38° 46′. Center the telescope on Vega and set the hour circle to 18h 36m. Then check the reading on your degree or declination circle, which should be close to +38° 46′. If it isn't, change the circle so that it reads correctly. While the telescope is centered on Vega, focus the camera sharply. (We'll discuss focusing later in detail.) The Ring Nebula's coordinates are 18h 53m and +33° 01′. This time move the telescope in right ascension and declination until your circles show the Ring's coordinates. If the Ring is not visible in the camera's finder, a bit of sweeping with the telescope should pick it up.

Guidescope *vs.* Off-Axis Guiding

Since polar alignment and the telescope's drive are rarely accurate enough to maintain the subject fixed in the camera's field during a long exposure, you must make guiding corrections more or less continually as long as the shutter remains open. Corrections in right ascension are generally made with the "fast" and "slow" buttons of a drive corrector, and declination corrections can be made with the telescope's slow motion control. These corrections are made with reference to a guide star, which is observed in a high power eyepiece (say 12mm focal length) equipped with illuminated crosshairs.

Since your 35mm camera body is attached to the telescope in the place normally occupied by the eyepiece, how can the guiding eyepiece be employed? Two methods are in use: the first uses a separate guidescope mounted on the scope to which the camera is attached; the second, an off-axis guider.

With a separate guidescope, locating a bright guide star is easier than with the off-axis guider, but guiding errors because of differential flexure between the guidescope and the photo scope are more likely. The off-axis guider

Astrophotographer Jack Marling made this splendid portrait of the Rosette Nebula (NGC 2237/9) in Monoceros by combining a deep-sky filter and hypersensitized TP 2415 to boost contrast. It is a 60-minute exposure made with an 8-inch f/4.5 Newtonian. Visible are some of the dark globules which may be giving rise to newborn stars. In the photo, north is at upper left, east at lower left.

is a device inserted between the main telescope and the camera body that uses a small prism to pick up the light from a star near the edge of the camera's field-of-view and divert it up into a tube in which the guiding eyepiece is inserted. Selecting a guide star, then, is limited to the field immediately surrounding the object to be photographed. Many of the galaxies you might wish to photograph are in star-poor regions of the sky, and you may find yourself, while shooting M51, for example, guiding with such a dim guide star that it can be seen only with averted vision! You *can* mount a separate guidescope on a tangent coupler. This allows the guidescope several degrees of sky in which to search for a guide star, while the main telescope remains pointed at the object to be photographed.

In my own deep-sky work, my through-the-telescope photos have been taken through an 8-inch or 14-inch SCT using an off-axis guider, but all of my shots with the 8-inch Schmidt camera have employed a separate 5-inch SCT guidescope.

Setting Up

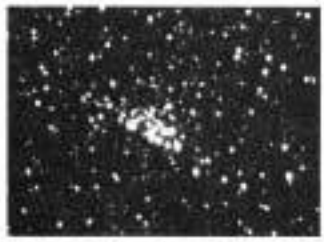
At this point we have our object to be photographed in the center of the camera's field, with the off-axis guider sandwiched between the camera and telescope or guidescope mounted atop the telescope.

Here I should add a word or two about cameras for deep-sky photography. Theoretically, any 35mm camera body with interchangeable lenses can be attached, via the proper adaptor, to the telescope. What limits the usefulness of "just any" 35mm camera, however, is the size, composition, and brightness of its viewfinder and focusing screen. In standard ground glass viewfinders that are perfectly adequate for snapshot work, many dim deep-sky objects are difficult or impossible to see. The Miranda Laborec camera that I use has an eyepiece-sized right-angle finder fitted with an adjustable diopter focuser. The camera also has interchangeable focusing screens: a ground glass screen for focusing the locator star, and a clear glass one for finding a dim object to be photographed (and for orienting the field so that the guidestar selected can be picked up by the guider's prism and directed into the guider's eyepiece).

Unfortunately, Miranda has gone out of business and the Laborec is no longer available. However, Robert Little, who once sold the Laborec, now offers a Practica camera body with similar modifications. I believe Olympus and Nikon 35mm cameras also have interchangeable focusing screens and accessory bright

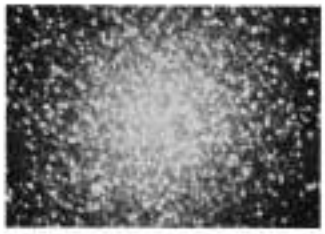
Roger Sliva

The Sombrero Galaxy



Star Cluster NGC 7510

Lee C. Coombs

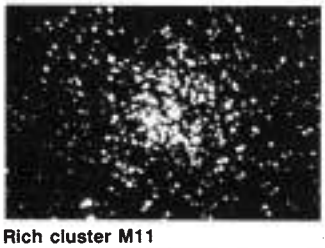


Alfred Lilge

ω Centauri

The Lagoon Nebula

Martin C. Germano

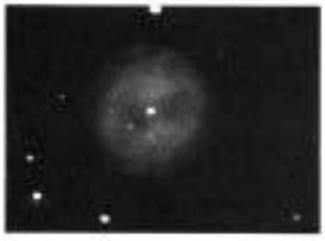


John Sanford

Rich cluster M11

The elusive California Nebula

Howard F. Zeh



Bryce Heartwell

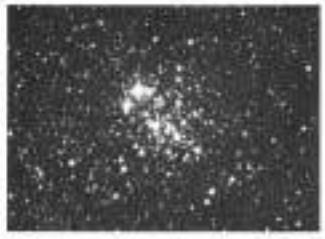
The Owl Nebula

Active galaxy M82

Martin C. Germano

Jack Child

Reflection nebula NGC 7023



NGC 457, the Owl Cluster

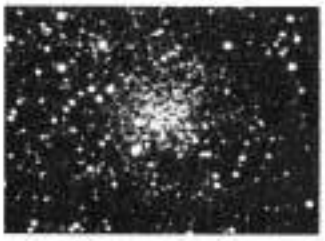
Lee C. Coombs

Martin C. Germano

The Bubble Nebula

Colliding galaxies NGC 4567/8

Jack Newton



Lee C. Coombs

Distant cluster NGC 2158

Bipolar nebula NGC 6302

Martin C. Germano

Top: NGC 6888, an unusual and difficult to observe nebulosity in central Cygnus, is easily recorded with a long photographic exposure. The nebula consists of matter flung out by a hot central Wolf-Rayet star. Photo by Martin C. Germano, who used an 8-inch f/10 SCT, 103a-F emulsion, and a 90-minute exposure. Subtle diagonal streaks are the remnants of an airplane trail. ***Above***: NGC 891 is a low surface brightness edge-on spiral in Andromeda. Paul Roques captured its narrow dust band and bright hub with a 90-minute exposure on hypered TP 2415 and a 10-inch f/10 SCT.

Paul Roques made this photograph of M16, the Eagle Nebula, using an 8-inch SCT and compressing lens for an effective focal ratio of f/5. Hypersensitized TP 2415 and a 120-minute exposure contributed to reveal dark obscuring matter across the face of the nebula, and subtle low surface brightness gas lying away from the young star cluster that lives in the Eagle's midsection.

finders. Ideally, a focusing screen should be clear (for picking out dim objects) but with a central ground glass spot (for focusing the bright locator star).

Focusing the Camera

Except for guiding errors, bad focusing is probably the most common way to ruin otherwise good deep-sky photos. At first I was not aware that focusing on a bright locator star with a clear focusing screen is highly unreliable. Even focusing with the ground glass can be tricky, and you'll do well to rack through focus (move to either side of the point of sharpest image) several times before deciding on the best focus. I have found that occasionally focus can change during an exposure, especially if the scope's temperature is dropping rapidly, and it is well to refocus before each exposure, too. Rotating the camera/guider combination to place a guidestar in the field of the guider's prism can also defocus the image, so it is desirable in this case to return the telescope to the locator star and refocus before starting the exposure.

It's a good idea after the locator star is focused, but before returning to the object to be photographed, to pick up the bright locator star in the guiding eyepiece. Then you can focus the guiding eyepiece. Do *not* focus the guiding eyepiece by turning the scope's focusing knob; this will throw the camera out of focus. Instead, focus the guiding eyepiece by sliding it in or out of its tube. At the same time, orient the guiding eyepiece so that moving the telescope in right ascension or declination will make a star move along one of the eyepiece's illuminated crosshairs. This makes it much easier to remember which type of guiding correction is needed and will cut down on guiding errors.

Setup is time consuming and repetitive, but it is nowhere near as time consuming or exasperating as having an otherwise perfect 45 minute exposure of a beautiful spiral galaxy ruined because the scope's focusing knob was off by $^1/_{25}$ of a turn or because you once leaned on the drive corrector's "slow" button when you should have leaned on the "fast" button.

Using a Focal Reducer

The focal ratio of many telescopes — particularly the refractors, Maksutovs and Schmidt-Cassegrains — is too high (and the resulting light levels at the film plane too low) for satisfactory deep-sky photography without special films, film treatment, cold cameras, etc. I would be reluctant to attempt deep-sky photos of all but a few of the brighter objects with a focal ratio higher than f/6 or so. Excellent deep-sky photos have

been made with f/11 systems, but they are rare.

The effective focal ratio of a telescope, however, can be cut in half (and the light levels at the film plane quadrupled) by the use of a converging lens or "focal reducer," placed between the off-axis guider and the 35mm camera body. Their use is not without compromise, however; the additional lens in the focal path involves some light loss and reduces image sharpness, particularly at the edge of the field. Additionally, image scale is reduced to about a quarter of the previous size and a vignetted field — the "porthole effect" — prevails. However, the fourfold increase in image brightness is usually rewarded by a reduction in exposure times of at least 75%, leaving a lot less time for fatigue-induced guiding errors, and giving you more photos per session.

The reduction in image scale is not a serious disadvantage because in practice, film grain and/or resolution does not often determine how sharp the picture will be. Guiding, seeing, and the "human factor" usually do. So most of my deep-sky photos (a few of the bright exceptions are M42, M13, and M104) were made with an 8-inch f/10 SCT converted to f/5, or a 14-inch f/11 SCT converted to f/5.5.

The Imperative "Odds and Ends"

Nothing ruins an astrophoto more effectively than a front lens or corrector plate fogged up like a bathroom mirror. On ordinary nights, a dewcap that extends about as far from the front lens as the scope's aperture will suffice to keep the outermost glass surface free of dew. On somewhat damper nights — or with an object near the zenith — a hair dryer will clear dew and warm the lens sufficiently so that it will stay dry for about twenty minutes or more. Telephoto lenses being used for piggyback exposures can actually be blown dry *during* an exposure if the hair dryer is held to the side. Not all dryers need house current — telescope companies offer models which run off of car batteries as well. If the hair dryer does not suffice, then an electrically-heated dewcap is a very good investment. You can even build one for a small amount.

And if the night is so soggy that not only front lens, but finderscope, ocular, camera, and spectacles need constant drying, give up! Flee to the Great Indoors and enjoy astronomy by reading about it. *Burnham's Celestial Handbook*, *Galaxies*, and back issues of DEEP SKY are recommended.

Do not neglect personal comfort. Be sure the guiding eyepiece will be as easily accessible at the end

***Top*: A challenging target for observers and astrophotographers, the curious "S" Nebula (lying at 17h20m, −23°45′) in Ophiuchus, also known as Barnard 72, is well rendered in this Al Lilge photograph. It is a 75-minute exposure on 098-1 emulsion, made with a 12.5-inch f/8 Ritchey-Chretien scope. In the photo, north is at upper left, east at lower left. *Above*: In another photo by Al Lilge, the contrasty trisecting dark lanes of the Trifid Nebula (M20) show well, as does the faint reflection nebulosity just north of M20. This is a 120-minute exposure made on 098-1 emulsion with the 12.5-inch f/8 Ritchey-Chretien.**

***Above*: Leo C. Henzl, Jr. photographed the giant globular cluster M22 in Sagittarius using a 14.25-inch f/6 Newtonian, hypersensitized TP 2415, and a 15-minute exposure. *Opposite top left*: David Healy recorded filamentary structure in the Crab Nebula (M1) with a 14-inch SCT and f/6 compressing lens, hypered TP 2415 film, and a 33-minute exposure duration. *Opposite top right*: The notorious 15th magnitude central star glows softly within M57 in Paul Roques' photo. Paul used an 8-inch f/10 SCT, hypered TP 2415, and a 40-minute exposure. *Opposite bottom*: Another Roques photo shows the knotty spiral structure of M51, the Whirlpool Galaxy, and its little companion NGC 5195. It is a 90-minute exposure on hypered TP 2415, made with an 8-inch f/10 SCT.**

of the exposure as at the beginning. And relax! A guiding position which is uncomfortable at the beginning of an exposure will be excruciating by the end of it. In the summer, apply insect repellent. In the winter, overdress massively. An inactive body chills rapidly in the cold, and even if you're warm when you start, you probably won't be when you finish. Better still, acquire an electrically heated suit. Last time I checked, Strand Surplus (2200 Strand, Galveston, Texas 77550) was offering WWII surplus "bunny suits" (!) for $15 each. (You'd have to rig up your own 12V, 24A power supply).

Do not neglect to check the scope's balance — the extra weight of the camera, etc. will mean adjustments to your counterweight. Aim to get the scope to hold its position or move only gently, when the right ascension and declination locks are released.

Astrophotography: Poetry in Motion?

Ben Mayer, an experienced California amateur, claims that "Murphy's Law" is an excuse for bad photo methods and that astrophotography, when carried out properly, is "poetry in motion." One hates to disagree with the producer of such superb astrophotos as Ben's, but *DSM* readers have my personal assurance that Mr. Murphy is alive and well (he was last seen two weeks ago ruining a star party with highly selective clouds). As far as astrophotography being "poetry in motion" — well. . . .

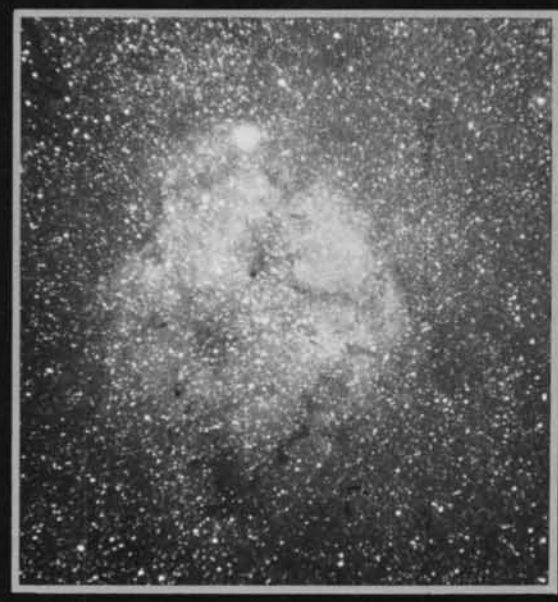
Tho' Ben Mayer says it is verse,
My astrophotography's worse.
While shooting a cluster,
I started to fluster,
And ended it all with a curse.

For while figuring out my f/tens
In poetical motion like Ben's
I forgot all the rules
From the booklets and schools,
And left the cap right on the lens!

Seriously, I think that on an excellent dark night, with everything from alignment to counterweighting working perfectly, few things can match the feeling of accomplishment and intellectual pleasure that comes from the knowledge that this picture, of anything between Pluto and the quasars, tests the capabilities of me and my equipment and captures a little piece of the universe so I can store it away for a cloudy night.

David Healy is a research executive at Drexel Burnham Lambert, Inc., a New York City brokerage house. He is an active astrophotographer and has contributed many articles to DSM.

OBSERVING LOW SURFACE BRIGHTNESS OBJECTS



Part One: Winter and Spring Targets

by Jeffrey Corder and David J. Eicher

The proliferation of large telescopes and increase in people interested in deep-sky observing have revealed major gaps in the traditional literature. Observing handbooks — recent ones included — all have a tendency to underestimate a telescope's capability in showing experienced observers faint nebular objects. Deep-sky targets such as the North America Nebula, the Veil Nebula, the Helical Nebula, M33, and M101 are time and time again referred to as "difficult" or "challenging" in small telescopes. Perhaps these opinions are weighted by the authors of these guides observing from less than desirable locations, or perhaps they are simply passed on gospel from pre-Webb days. ("If so-and-so didn't see it with a 4-inch, it must be impossible!") But whatever the reason, we feel that much more is visible with small telescopes than is usually taken for granted. For example, the Veil Nebula, once upon a time a difficult and rarely observed object, is routinely visible in an 8-inch SCT from a fairly good site.

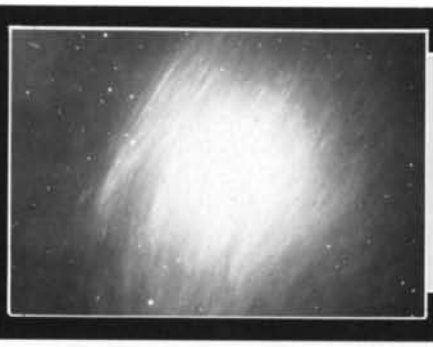
In two parts — the second appearing in DSM 7 — we'll look at some of the "taboo" low surface brightness objects: some of the ones you may have detected with your small backyard scope, although you weren't *supposed* to!

Low surface brightness (LSB) objects are those whose often substantial amount of light is spread over a large sky area, making individual parts appear rather dim. They tend to be nebular: the 40 LSB objects covered in this two-part series include 14 emission nebulae, 11 galaxies, three reflection nebulae, three dark nebulae, three supernovae remnants, and two planetary nebulae. The only exceptions are four sparse and/or distant globular clusters, which appear nebular because they are difficult to resolve.

LSB objects live and die by transparency — the amount of light

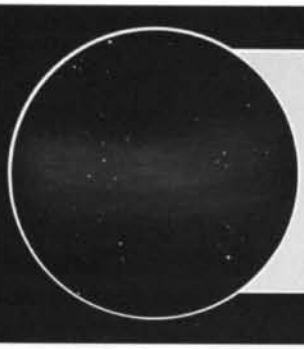
IC 342

is a large nearby spiral in Camelopardalis, and is difficult to observe because it lies near the Galactic plane. Sketch by David Godin; 8-inch f/10 SCT at 70x. The photo is a product of Flagstaff's 61-inch astrometric reflector: official U.S. Naval Observatory photograph.



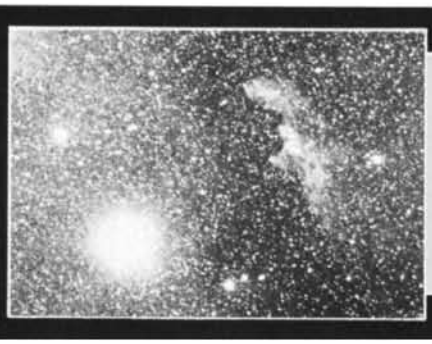
The Merope Nebula

is catalogued as NGC 1435, the faint reflection gas that surrounds the star Merope in the Pleiades cluster. Set in a field of bright blue-white stars, the 20′ diameter wisp is difficult to spot. Sketch by Chuck Coates; 12.5-inch f/5 Newtonian at 67x. Four-meter Mayall telescope photo courtesy Kitt Peak.



The California Nebula

is one of the most elusive objects for most observers; its total magnitude of about 6 is spread over a huge area of sky, making its surface brightness around 14. Sketch by Richard P. Wilds; 2-inch f/12 refractor at 15x. Photo by Rick Dilsizian; 8-inch f/1.5 Schmidt camera, hypersensitized TP 2415, 12-minute exposure.



The Witch Head Nebula

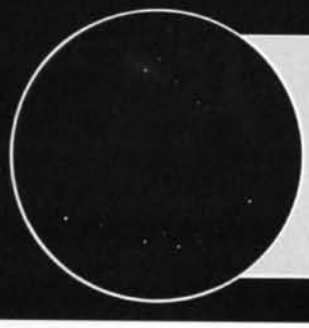
is exceedingly faint and may not be observable visually. Known as IC 2118, it is a reflection nebulosity spreading over an area approximately equal to that of the California, but its surface brightness is probably about 15. DSM has no visual observations of this object — can you see it? The photo shows IC 2118 photographed by Ross at Yerkes Observatory in 1927.

scattering off matter suspended in Earth's atmosphere. About 90 percent of our atmosphere exists within the first vertical 10 miles; the amount, type, and behavior of particles in this region drastically affect the visibility of LSB objects. It affects their visibility so much that a good observing site is equally as important as telescopic aperture. Cloud condensation, fog and mist, smoke fog, suspended solid particles and corrosive gases, and condensation nuclei do their best to raise the sky's background light to a level where it hides a galaxy's image.

The ultimate trick is to seek the highest ground possible in order to look through the least amount of atmosphere and find the cleanest, darkest, steadiest air possible. The reason old Reverend Webb described M33, considered a bright object these days, as "large, faint, and ill-defined," was more because his notoriously damp homeland of England is a generally poor site than because M33 is especially difficult.

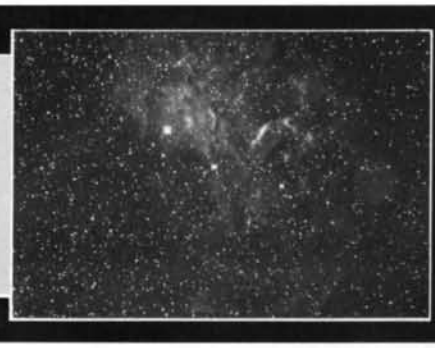
Observing technique plays a critical role in finding LSB objects. You must give yourself at least 15 minutes — preferably 35 minutes — without light of any kind to become properly dark-adapted. Make sure that your red filtered flashlight — your light source for briefly checking positions on a star atlas — has several layers of red cellophane or nail polish remover. Use your flashlight as little as possible and keep it as dim as possible: don't strain your eyes, but don't flood them with unneeded photons.

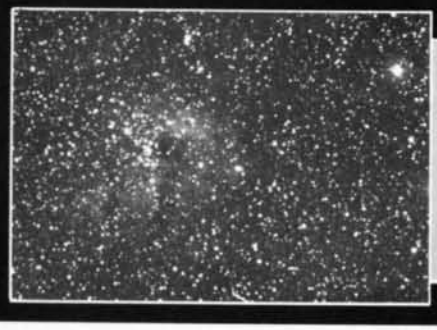
Two "tricks of the trade" will help you identify subtle nebulosity: averted vision and field sweeping. Averted vision is simply looking off to one side of the field and maximizing your rods' sensitivity on the outer edges of your eye. Field sweeping is slowly and methodically moving the telescope around the suspected area of nebulosity in order to detect slight changes in the sky



IC 405

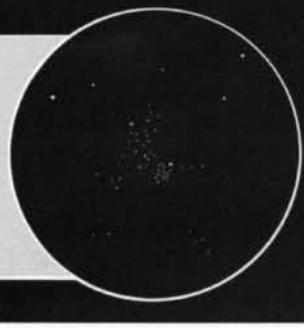
is sometimes called the "Flaming Star Nebula." It is a difficult object — its surface brightness is approximately 14.5 — but is visible even with small telescopes with filters under excellent conditions. Sketch by Don Stotz; 2.4-inch f/12 refractor, 17.5x. Photo by Ronald Royer; 18-inch f/7 Newtonian, red sensitive emulsion.





IC 410

is easier to spot than nearby IC 405, as it is marginally brighter and lies within the bright open star cluster NGC 1893. Sketch by Dave Eicher; 8-inch f/5 SCT, 35x. Photo by Rick Dilsizian; 8-inch f/1.5 Schmidt camera, hypersensitized TP 2415, 10-minute exposure.



NGC 1973/5/7

is a broad and relatively easy reflection nebula north of the Orion Nebula. Although it is brighter than the Merope nebulosity, it suffers from lying within the same field as a bright star (in this case 42 Orionis). Sketch by Dave Eicher; 8-inch f/10 SCT, 170x. Photo by Martin C. Germano; 8-inch f/10 SCT, 103a-F emulsion, 20-minute exposure.

The Horsehead Nebula

is one of the most difficult visual targets in the entire sky. Try your best seeing, transparency, large optics, and nebula filters on this one — and don't be discouraged if the Horsehead just doesn't seem to be there! Sketch by Lee Cain; 13.1-inch f/4.5 Newtonian, 60x. Photo by Ron Potter; 8-inch f/1.5 Schmidt camera, hypersensitized TP 2415, 15-minute exposure.

background brightness — on the fainter objects, it is often the only way to detect them.

Now taking a look at our objects in right ascension order, the first LSB target we come to is the large spiral galaxy **IC 342** in the faint constellation Camelopardalis. At a distance of 1.51 megaparsecs (Mpc) this galaxy is a member of our Local Group, but lies only 10° above the galactic plane — thus it is rather difficult to observe visually. Discovered by the astronomer W.F. Denning around 1890 and included in the first *Index Catalogue* in 1895, this system was first detected photographically because its light is so spread out. The system has a blue magnitude of 9.1, but covers 225 square arcminutes, making its mean surface brightness somewhere around 15.2 per square arcminute.

Brighter than IC 342's spiral arms is **NGC 1435**, the Merope Nebula. This 20 arcminute diameter patch of bluish reflection nebulosity is a prime target for difficult object hunters at star parties, yet under dark skies — and with the 4th magnitude star Merope just out of the field — it is reasonably easy to spot with a 4-inch scope. It should be, as it was discovered by W. Tempel at Venice in 1859: he likened it to "breath on a mirror." Comet hunter Lewis Swift observed it with a 2-inch refractor in 1874. Its surface brightness of around 13th magnitude makes it easy for large telescopes; the trick is keeping away from Merope's glare.

One of the most sought-after emission nebulae is **NGC 1499**, the California Nebula in Perseus, whose gigantic proportions (over 5800 square arcminutes) contribute to a surface brightness of around 14.0. Experienced observers know that it takes a night of excellent transparency and at least a 12-inch or 14-inch RFT to even consider looking at the California Nebula. The California certainly is visible over several fields of view in these

Barnard's Loop

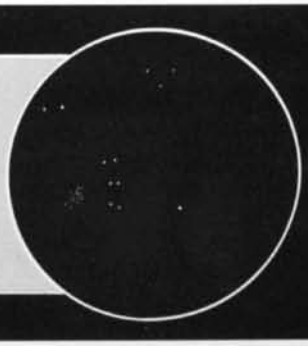
is a staggering goal in visual deep-sky observing: several independent observers have spotted it with the naked eye, using high-grade nebula filters that emphasize red light. We have no sketch of such observations — someone go out and sketch this object and send a copy to DSM! Photo by John Davis and William Toban; 50mm f/1.8 lens, Tri-X, 45-minute exposure.

IC 443

is a fantastically difficult — if not impossible — object to observe visually. It is a large loop of emission gas, most likely in the form of a supernova remnant, near the bright star Eta (η) Geminorum. Its surface brightness is so low that we don't have any sketches of this object — someone who lives in the middle of Montana please help! Photo by the Palomar 48-inch Schmidt.

The Rosette Nebula

is catalogued as NGC 2237/9 and surrounds the bright star cluster NGC 2244. The large ring of emission gas constituting the Rosette is elusive, and requires a gigantic field of view and dark skies. Sketch by Richard P. Wilds; 2-inch f/12 refractor, 15x. Photo by John W. Parker; 5.5-inch f/1.65 Schmidt camera, hypersensitized TP 2415, #92 red filter, 30-minute exposure.



NGC 2264

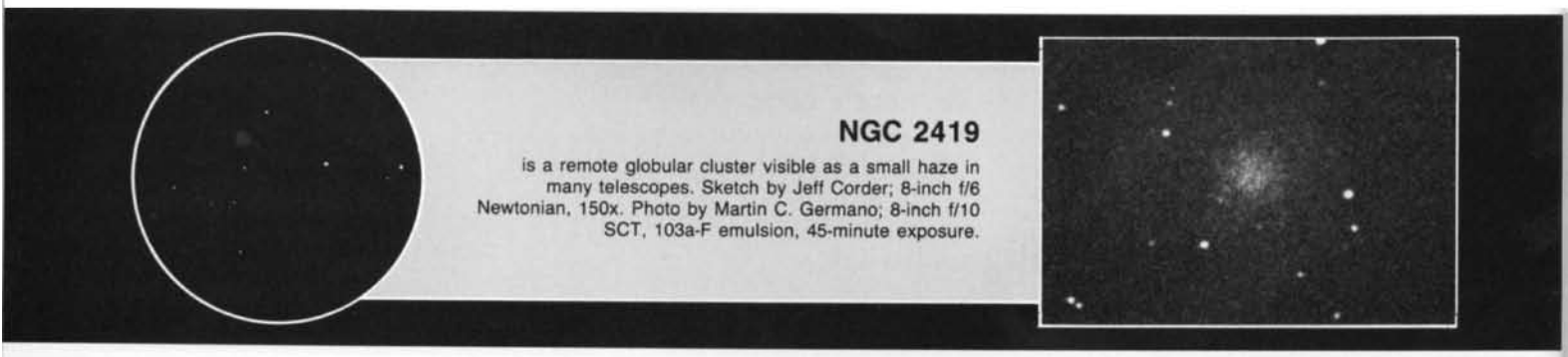
is a giant complex of faint nebulosity primarily surrounding the star S Monocerotis; it is difficult to observe in most telescopes. NGC 2264 contains the Cone Nebula, a dark nebulosity easy to see with large apertures on good nights. Sketch by Dave Eicher; 8-inch f/5 SCT, 35x. Photo by Richard Hill, Kitt Peak National Observatory.

instruments, but there is another possibility: NGC 1499 is large and its total visual magnitude is probably around 6, so under very black skies, a good nebula filter reveals the giant nebula as a dim arc to the naked eye!

A curious low surface brightness object is **IC 2118**, the Witch Head Nebula in northern Eridanus. This giant loop of reflection nebulosity is illuminated by Rigel (Beta [β] Ori), which is located some 2.5° away. With a sky area of 5600 square arcminutes, this nebulosity is almost as large as the California, but fainter yet. The object probably has a surface brightness of 15 or below, so it is a difficult mark for any telescope. Perhaps a nebula filter may reveal this loop to keen naked eye observers. At present we know of no visual observations of IC 2118 — has anyone out there ever seen it?

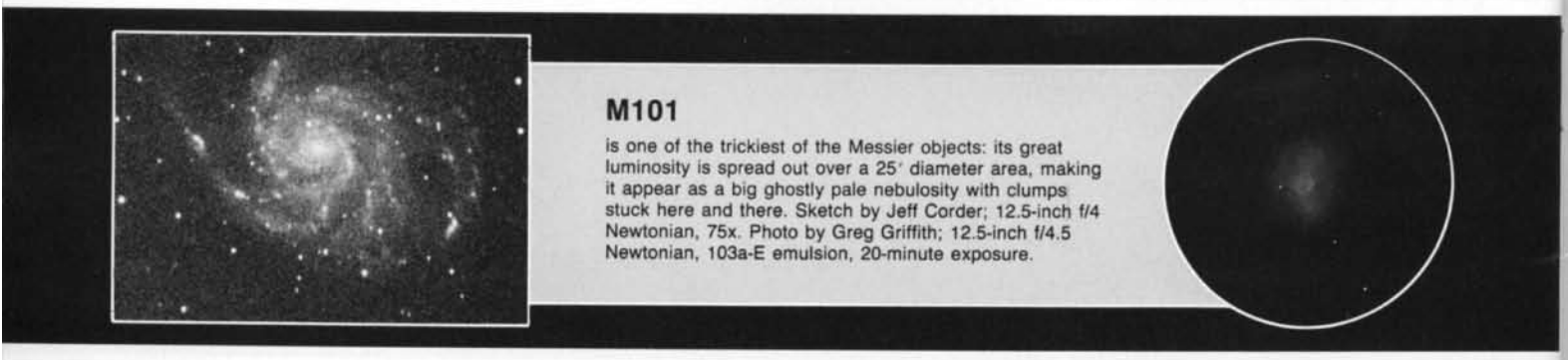
IC 405 and **IC 410** are a couple of large, low-luminosity emission nebulae located in central Auriga. IC 405, sometimes called the Flaming Star Nebula, surrounds the unusual variable star AE Aurigae, which shines around 6th magnitude excepting for small irregular ups and downs. This object has a combined magnitude of around 10, a total sky area of around 540 square arcminutes, and a resultant mean surface brightness of about 14.5. It is a difficult target for telescopes, but an 8-inch reflector on a dark night shows a faint wisp of haze. Much easier to observe visually is IC 410, which surrounds the magnitude 7.5 open cluster NGC 1893. With a total magnitude somewhere near 9.0 and sky coverage of around 300 square arcminutes, IC 410 has a surface brightness of 14.0.

Nearby in Orion, the faint reflection nebulosity **NGC 1973/5/7**, lying just 30′ north of M42 and surrounding the star 42 Orionis, suffers slightly from the old Merope problem of a bright star lying near the faint gas. The star 42 Ori is a double composed of magnitude 5.5 and



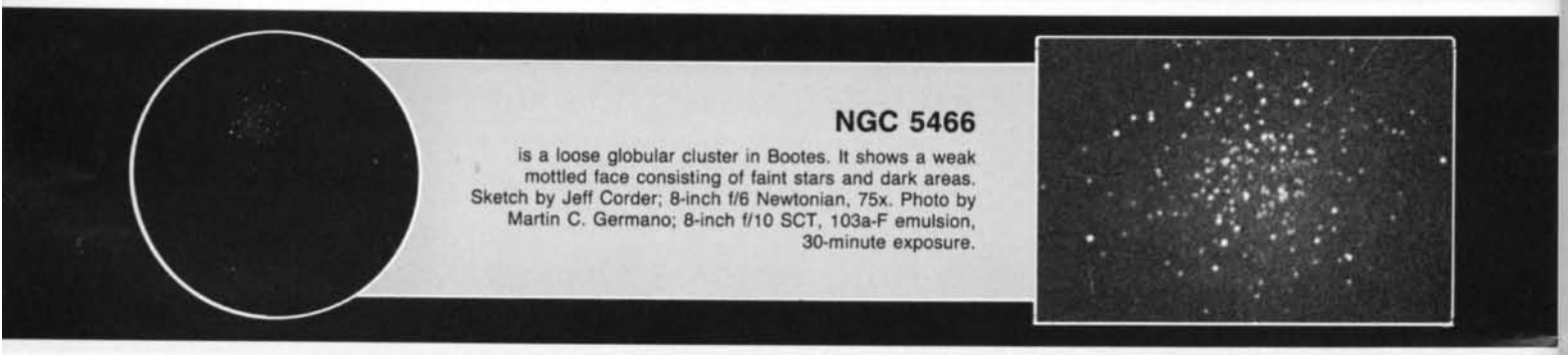
NGC 2419

is a remote globular cluster visible as a small haze in many telescopes. Sketch by Jeff Corder; 8-inch f/6 Newtonian, 150x. Photo by Martin C. Germano; 8-inch f/10 SCT, 103a-F emulsion, 45-minute exposure.



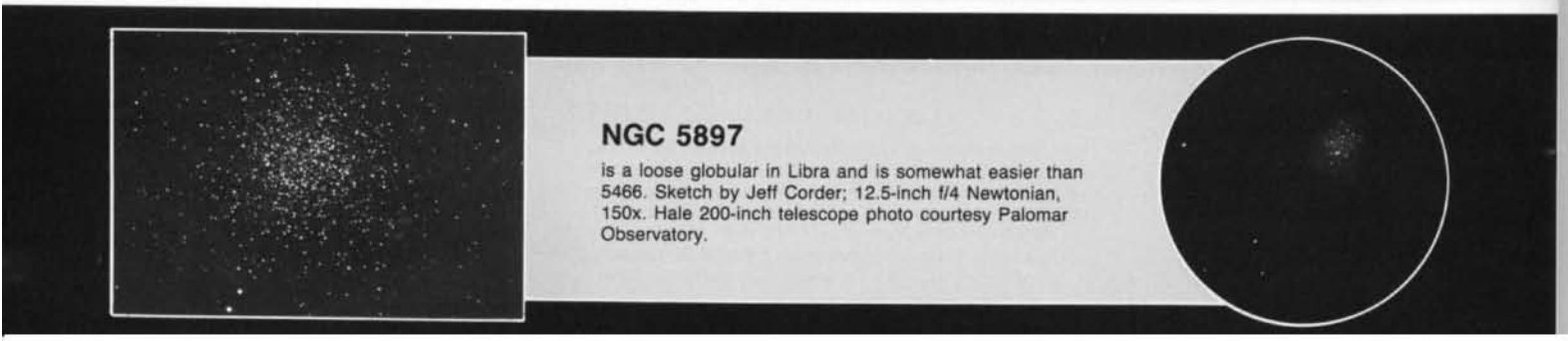
M101

is one of the trickiest of the Messier objects: its great luminosity is spread out over a 25′ diameter area, making it appear as a big ghostly pale nebulosity with clumps stuck here and there. Sketch by Jeff Corder; 12.5-inch f/4 Newtonian, 75x. Photo by Greg Griffith; 12.5-inch f/4.5 Newtonian, 103a-E emulsion, 20-minute exposure.



NGC 5466

is a loose globular cluster in Bootes. It shows a weak mottled face consisting of faint stars and dark areas. Sketch by Jeff Corder; 8-inch f/6 Newtonian, 75x. Photo by Martin C. Germano; 8-inch f/10 SCT, 103a-F emulsion, 30-minute exposure.



NGC 5897

is a loose globular in Libra and is somewhat easier than 5466. Sketch by Jeff Corder; 12.5-inch f/4 Newtonian, 150x. Hale 200-inch telescope photo courtesy Palomar Observatory.

8.5 components — bright enough to interfere with subtle nebular light. Use medium magnifications and move the star slightly out of the field. You should see an elongated bright mass of milky light covering roughly 1000 square arcminutes and glowing with a surface brightness of about 12.

Always controversial is the visibility of **Barnard 33**, the Horsehead Nebula in Orion. Found about 30′ south of the second magnitude double Zeta (ζ) Ori, the Horsehead is notoriously difficult to find. It is a tiny dark patch of dust silhouetted against the luminous band of emission nebulosity IC 434, and is visible only on black, black nights if one knows exactly where to look. Some observers have spotted the Horsehead with 5-inch and 6-inch refractors, but others have failed to see it with 40-inch observatory reflectors! Perhaps even more difficult is the gigantic **Barnard's Loop**, which covers 504,000 square arcminutes and has a probable total magnitude of 6. Possibly an old supernova remnant, it has a mean surface brightness something like 15 — a rough object to hunt for with a large scope. It is probably visible to the naked eye with the aid of a nebula filter, providing transparency is at its best.

Three more interesting winter nebulosities are **IC 443** in Gemini and **NGC 2237/9** and **NGC 2264** in Monoceros. IC 443 is a rather small — 125 square arcminute — supernova remnant which has a total magnitude of 12 and a surface brightness of around 13.5; it is visible with an 8-incher on good nights. NGC 2237/9 surrounds the bright star cluster NGC 2244 and is the famed Rosette Nebula; a difficult target for narrow field scopes, it snaps into view with an 8-inch f/5 under dark skies as a large, ghostly ring of faint nebulosity covering 4800 square arcminutes. Its surface brightness is around 12.5. NGC 2264, a faint emission nebulosity surrounding the variable S Mon, covers 1800 square

Winter and Spring Low Surface Brightness Objects

Type	Designation	R.A. (2000) Dec.	Mag	SB	Size	Con
§	**IC 342**	3h46.8m +68°06′	9.1_B	15.2	15.0′ x 15.0′	Cam
	Large Sc-type spiral which, at a distance of 1.51 Mpc, is a probable member of the Local Group and one of four closely neighboring spirals (the others being M31, M33, and Maffei 1). Diameter = 7.7 kpc; luminosity = 10 million $L_\odot$; Hubble classification: SAB(rs)cd.					
□R	**NGC 1435**	3h46.3m +23°57′	18.0_v	13.0	20.0′	Tau
	The Merope Nebula. A large irregular filamentary wreath of reflection nebulosity surrounding M45, the Pleiades Cluster. Lies at a distance of 125 pc.					
□E	**NGC 1499**	4h04.2m +36°25′	6.0_v	14.0	145.0′ x 40.0′	Per
	The California Nebula. A large emission nebula, its center lies 36′ north of Xi [ξ] Per, its mag. 4.0 illuminating star. Lies at a distance of about 600 pc, and contains about 240 $M_\odot$.					
□R	**IC 2118**	5h06.9m − 7°13′	?	15.0	140.0′ x 40.0′	Eri
	The Witch Head Nebula. A large reflection nebulosity apparently illuminated by Rigel (Beta [β] Ori), some 2.5° away.					
□E	**IC 405**	5h16.3m +34°18′	10.0_v	14.5	30.0′ x 18.0′	Aur
	A faint emission nebula illuminated by the erratic variable star AE Aur (V mag. 5.4-6.1). Its extent is about 2.8 pc; it lies at a distance of about 491 pc.					
□E	**IC 410**	5h19.3m +33°28′	9.0_v	14.0	20.0′	Aur
	Faint emission nebula encapsulating the bright (V mag. 7.5) open cluster NGC 1893.					
□R	**NGC 1973/5/7**	5h35.4m − 4°50′	7.0_v	12.0	40.0′ x 25.0′	Ori
	Large reflection nebula complex whose three brightest parts surround bright stars (the brightest nebulosity, NGC 1977, is centered on 42 Ori, a V mag. 4.6 star).					
□D	**Barnard 33**	5h41.2m − 2°31′	12.0_v	15.0	4.0′	Ori
	The Horsehead Nebula. This tiny patch of dust grains — about one third of a parsec across (or 70,000 times the distance between the Earth and the Sun) — is visible silhouetted against the faint emission nebula IC 434. The distance to B33 is about 430 pc.					
□E	**Barnard's Loop**	5h55.0m − 1°30′	6.0_v	15.0	840′ x 600′	Ori
	Possibly an ancient supernova remnant, Barnard's Loop was discovered photographically by E.E. Barnard in 1895 and is a devilishly difficult visual target. A giant cosmic bubble, Barnard's Loop contains large amounts of dust and is perhaps 3 million years old.					
SNR	**IC 443**	6h16.5m +22°47′	12.0_v	13.5	25.0′ x 5.0′	Gem
	One of the best examples of a supernova remnant after M1, the Veil Nebula, and NGC 6888. This little shell of emission gas is a strong radio source.					
□E	**NGC 2237/9**	6h32.4m + 4°51′	8.9_v	12.5	80.0′ x 60.0′	Mon
	The Rosette Nebula. A giant wreath of emission nebulosity surrounding the bright (V mag. 4.8) open cluster NGC 2244. One of the most massive known nebulae, at 11,000 $M_\odot$. The distance to the Rosette is about 1700 pc, and its actual diameter some 16.8 pc.					
□E	**NGC 2264**	6h41.1m + 9°51′	12.0_v	14.0	60.0′ x 30.0′	Mon
	Faint emission nebulosity surrounding the star S Mon (mag. 4.5; slightly and irregularly variable). This nebulosity outlines the Cone Nebula, a dark object roughly equivalent to the Horsehead. The distance to NGC 2264 is about 750 pc.					
●	**NGC 2419**	7h38.2m +38°53′	10.8_v	12.0	4.1′	Lyn
	The 'Intergalactic Wanderer'. This globular cluster — at a distance of 90 kpc from us and 98 kpc from the galactic center — is among the most distant globular clusters belonging to the Milky Way. Contrary to its nickname, it is a dynamical member of the Galaxy, at apogalacticon. Diameter: 107 pc; luminosity: 3.6 x 10^5 $L_\odot$.					
§	**NGC 5457**	14h03.3m +54°21′	7.7_v	14.7	26.9′ x 26.3′	UMa
	Messier 101. A large Sc-type spiral with a mass of 16 billion $M_\odot$, M101 is one of the nearest face-on galaxies (at a distance of 6.9 Mpc). It is rather large for an Sc galaxy (53 kpc across), and has a low density of only 1 $M_\odot$ per cubic pc. Hubble classification: SAB(rs)cd; supernovae: 1909 (mag. 12), 1951 (fainter than 12th mag.), and 1970 (11th mag.).					
●	**NGC 5466**	14h05.5m +28°32′	9.4_v	12.0	11.0′	Boo
	A loose globular cluster. Distance from Sun: 16.2 kpc; distance from galactic center: 16.9 kpc. Diameter = 52 pc; luminosity = 41,000 $L_\odot$.					
●	**NGC 5897**	15h14.5m −20°50′	8.6_v	11.5	12.6′	Lib
	A loose globular cluster. Distance from Sun: 11.7 kpc; distance from galactic center: 6.6 kpc. Diameter = 43 pc; luminosity = 61,000 $L_\odot$.					

Column 1 = type code: ● = globular star cluster; □E = emission nebula; □R = reflection nebula; □D = dark nebula; SNR = supernova remnant; § = spiral galaxy. **Column 2** = name in *Revised New General Catalogue* and additional lists. **Column 3** = coordinates for epoch 2000.0. **Column 4** = integrated magnitude in V (visual) or B (blue) light. **Column 5** = mean surface brightness (magnitude per square arcminute). This is the best indicator of what you see in your telescope. **Column 6** = angular size in arcminutes. **Column 7** = constellation in which object lies. Data for open clusters from *Catalogue of Open Cluster Data*, 3rd edition, by G. Lyngå. Data for globular star clusters from G. Alcaino, *PASP* **89**:491, 1977, and Racine and Harris, *ApJ* **196**:413, 1975. Data for galaxies from de Vaucouleurs and Corwin, *Second Reference Catalogue of Bright Galaxies*. Estimated high-end mean surface brightness data by D. Eicher and B. Skiff.

arcminutes and backlights the dark nebula known as the Cone Nebula. This isn't easy to observe; let us know how different apertures work on this object.

Spring skies bring three faint globulars: **NGC 2419** in Lynx, **NGC 5466** in Bootes, and **NGC 5897** in Libra. NGC 2419 is one of the most distant known globulars, at 90 kpc, and is also one of the largest — measuring 107 pc across. It appears as a tiny grainy patch in amateur telescopes, with about a 12th magnitude surface brightness. Is it possible to achieve any resolution on 2419 with a large backyard telescope? NGC 5466 is quite loose and close at 16.2 kpc; large amateur scopes show a mottled face which can appear nebulous on less than perfect nights. The same holds for the slightly brighter NGC 5897, which has a surface brightness of around 11.5.

The large loose Sc-type spiral galaxy **M101** in Ursa Major is a difficult galaxy with respect to its bright total magnitude of 7.7. Small scopes show nothing more than a compact hazy core, a disappointing sight. But dark nights coupled with a 10-inch or larger scope reveal a multitude of nebulous patches tucked in and around the milky arms of the galaxy (see Letters, DEEP SKY 5). The mean surface brightness is about 14.7, and the nebulosity covers a total area of around 707 square arcminutes.

We've covered some of the best low surface brightness objects for the winter and spring skies; in DEEP SKY 7 we'll extend our list to cover the summer and fall skies, looking at another 22 such objects. In the mean time, let DSM know how you're doing finding, observing, and photographing these and other objects. We'll publish observations from readers either in Letters to DSM, a special section of readers' reports, or both. Inquiries and observations should be addressed to the editor.

Jeff Corder is an avid observer who lives in North Carolina.

Double Stars

Doubles in Corvus the Crow

by Glenn F. Chaple, Jr.

During the last four seasons, we've presented a parade of the finest double, triple, and multiple stars visible from mid-northern latitudes — 100 in all. I hope you were able to view at least a few of these gems. If you notched most or all of them, congratulations!

Of course, these "Top 100" are but the tip of the iceberg. Thousands of their brethren, in a dazzling array of colors, magnitudes, and separations, are within the grasp of modest-sized telescopes. (I've caught nearly 1500 with the 3-inch mirror of a reflecting telescope I own.)

Beginning with this column, we'll be returning to the format of the "old" *Deep Sky* — namely, an in-depth look at the double and multiple stars which inhabit a certain constellation or region of sky. The selection ought to provide something for everyone, from binocular users to owners of large Dobsonians. Your comments are always welcome, and a readers' forum — "Double Takes" — will appear at the end of each column.

This time, we'll concentrate on the constellation Corvus, the Crow, an intriguing little quadrangle of third-magnitude stars. It lies rather low in the southern sky when viewed from my vantage point here in Massachusetts, but to those whose more southerly latitudes place it higher up, the Crow must be a striking sight.

Within the confines of the Crow's body lies **Zeta** (ζ) **Corvi**. Binoculars show that this 5th magnitude star has a 6th magnitude partner roughly 7 arcminutes to the west. Each of these two stars is also double, but neither is resolvable with the size telescopes most of us amateurs own.

Delta (δ) **Corvi**, the uppermost star in the quadrangle, was one of my "Top 100" selections. It's a lovely unequal pair that can be a bit difficult for my 3-inch f/10 reflector. I advise small-scope owners to use medium to high magnifications (60x to 90x) and averted vision to bring the faint partner into view. According to *Burnham's Celestial Handbook*, this little star is a K-type dwarf whose luminosity is about half that of our Sun.

It's too faint to register any color in my 3-inch, but a scope with twice the aperture should reveal the characteristic orange color of a star of that spectral class. The primary is 75 times brighter than our Sun and is separated from its partner by a gap that could hold over a dozen solar systems laid end to end. We might expect the orbital motion of such a wide system to be extremely slow and, sure enough, Delta Corvi has essentially the same separation and position angle it had when discovered by J. Herschel and J. South in 1823.

John Herschel (whose father, William, was the celebrated discoverer of Uranus) and James South were early 19th century English astronomers who, independently and in collaboration, made numerous double star discoveries. Two of the pairs South discovered in Corvus are bright and wide enough for small scopes. **S634** is a delicate-looking magnitude 7 and 8 pair located a little over a degree northwest of Gamma (γ) Corvi. During the past century, S634 has closed slightly to its present separation of 5.5 arcseconds. Use 75x to 90x for this beauty.

Much father apart are the magnitude 7.5 and 9 suns that make up **S643**. The main difficulty with this pair is in finding it — S643 lies in a barren region near the Virgo border. The best of John Herschel's Corvus finds is **h4481**, a pair situated so close to the Corvus-Crater border that it appears in the double star listings for both constellations in *Burnham's*. A 3-inch scope can handle the 3.6 arcsecond separation of h4481, but because the component stars are rather faint (both 8th magnitude), I recommend apertures of 4 inches or more. To find h4481, look 3° west of Epsilon (ε) Corvi.

Another prolific early 19th century double star observer was the Russian astronomer Friedrich G. W. Struve. During the mid-1820's, his systematic survey of the heavens down to −15° declination netted over 3000 pairs. One of these — **Σ1669** — is most certainly the finest double star in Corvus. A shoo-in for my "Top 100" list, this pair of 6th magnitude near-twins lies 4½° northeast of Delta Corvi. I wonder if Struve was as entranced by these celestial cat's-eyes as I was when I first saw them thirteen years ago.

Just 1½° northwest of Σ1669 is a Struve pair not mentioned in *Burnham's*. This is **Σ1659**, and it's certainly worth a few minutes of your time. What I find most appealing about this twosome is its immediate field: it lies between two 7th magnitude stars and makes a striking sight in my 3-inch reflector at 60x. (Before you leave this area, be sure to check out M104, the Sombrero Galaxy — a famous edge-on spiral which lies in nearby Virgo. Even a 2.4-inch refractor will show this 8th magnitude elliptical glow, but a 6-inch or larger is normally needed to bring into view the prominent dust lane.) Our final Struve entry is **Σ1604**. This 6th magnitude star is accompanied by two 9th magnitude companions, the outermost of which is optical — that is, the pairing is due only to a chance alignment, not to any physical connection.

To wrap up our exploration of Corvus, let's turn to **Howe 26**. Thus far, this double has eluded my 3-inch reflector, largely because its southerly declination subjects it to the whims of atmospheric distortion. Can any readers bag Howe 26 with a small scope?

DOUBLE TAKES: A tip of the hat to Paul Brown of Goderich, Ontario. A few months back, this dedicated double star observer notched his 1500th pair. Paul isn't about to rest on his laurels; he's still tracking down new doubles and hopes some day to own a filar micrometer for making precise measurments of stellar separations.

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STAR	R.A. (2000) Dec.	Mags	Sep.″	P.A.	Year
Zeta (ζ)	12h20.6m −22°13′	5.3, 6.3	420	280°	1979
Delta (δ	12h29.9m −16°31′	3.1, 8.4	24.2	214°	1958
S634	12h11.4m −16°47′	7.2, 8.4	5.5	291°	1960
S643	12h54.0m −18°02′	6.8, 9.3	23.4	294°	1915
h4481	11h57.3m −22°32′	8.0, 8.1	3.6	194°	1954
Σ1669	12h41.3m −13°01′	6.0, 6.1	5.4	309°	1958
Σ1659	12h35.8m −12°02′	8.0, 8.1	27.4	351°	1922
Σ1604	12h08.4m −11°51′	6.5, 9.4	10.0	89°	1959
Hwe 26	12h21.5m −24°13′	8.5, 8.5	5.2	150°	1929

Variable Stars

Spring's Variable Lions

by David H. Levy

One bitterly cold January night, I first watched R Leonis. A front had just passed through, leaving a crisp starry sky. Checking my variable star chart, I began to look for R Leo. After a bone-chilling 45-minute search I finally found R Leonis as it rose through the haze and smog that hugged the eastern horizon that frosty Montreal night. I was so cold that even the simplest and smallest activities were magnified into an agonizing exercise that taxed my whole concentration. All this for a faint magnitude 9.3 star, graced by two companion stars at 9.1 and 9.6. Quickly, observer minus telescope moved inside for a warmup. It was so-o-o-o cold that the telescope tube froze to its mount and I couldn't even take the poor instrument inside. Never did hot chocolate taste so good!

But outside and hundreds of light-years away, shone my new variable friend. On that frigid night, R Leonis taught me two important lessons. The first was that variable star observing is a vocation that can be challenging and worthwhile. The second? To observe variables properly, you must first acquire a feeling for them, a genuine concern for what they are doing, and a will to endure some discomfort.

In the following nights and years I have been able to make estimates with greater ease. Instead of 45 minutes, I now need but that many seconds to find and estimate R Leonis. And instead of it being the sole estimate of a long night, it may be one of 10 or even 25. The challenge is the same, only the degree is different.

At the end of each month, I look over my record to see what I have done. Some months the total number has been high, especially with good weather. But if the month has been clouded either by stormy weather or personal commitments, the month's total may be low.

R Leonis helped teach me that totals are not important. As amateurs, we are interested in variables not because they provide us with a means to do more than the next observer, but to enjoy and learn from them. We are committed not to numbers but to the variables themselves and to the spirit of scientific inquiry.

R Leo's period of just under a year is typical of Mira stars. But its curve is not textbook smooth — I found that out during the first year, beginning on that January night. After the star had steadily risen two magnitudes from minimum, it suddenly stopped! For a whole month R just sat there, halfway between maximum and minimum, doing nothing besides adjusting itself by a few tenths of a magnitude here and there. I was sure that it would be late for its predicted May maximum. But toward the end of April, R Leonis woke up and hurried along, arriving at maximum only a few days after prediction!

When you watch R Leonis, you may notice such a standstill, or the light curve may be smoother. It is uncertainties such as this that make R Leonis, a "typical" long period variable, such a thrill to watch.

Of Star and Man

Last issue, I mentioned how each new AAVSO observer receives a package of about 10 introductory charts, that this set traditionally includes maps of R Leonis, and that this was the first star that Leslie C. Peltier watched. I would like to tell you more about this remarkable man.

I owe much of my interest in variable stars to a cloudy night early in 1966 and to Leslie Peltier's autobiography, *Starlight Nights* (try your library for a copy).

Those of us who know and love R Leonis have had a hard time thinking about it without also thinking of Leslie Peltier's special relation to this curious star. He began his observations with a 2-inch brass telescope mounted on a heavy stand that used a discarded grindstone as its azimuth support.

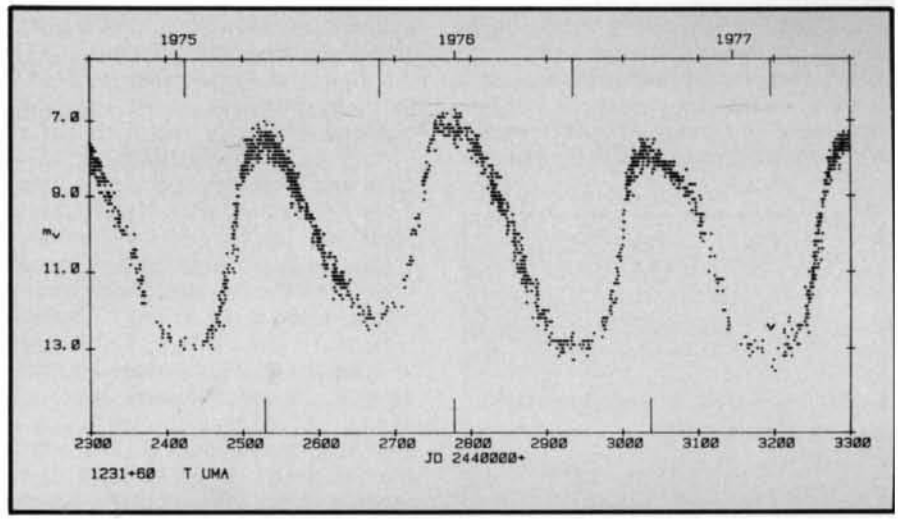
Peltier's first variable star experience occurred in February 1918. Having just received his introductory set of charts from the AAVSO, he set up his telescope on another bitterly cold night, a half century before mine, to search for variables.

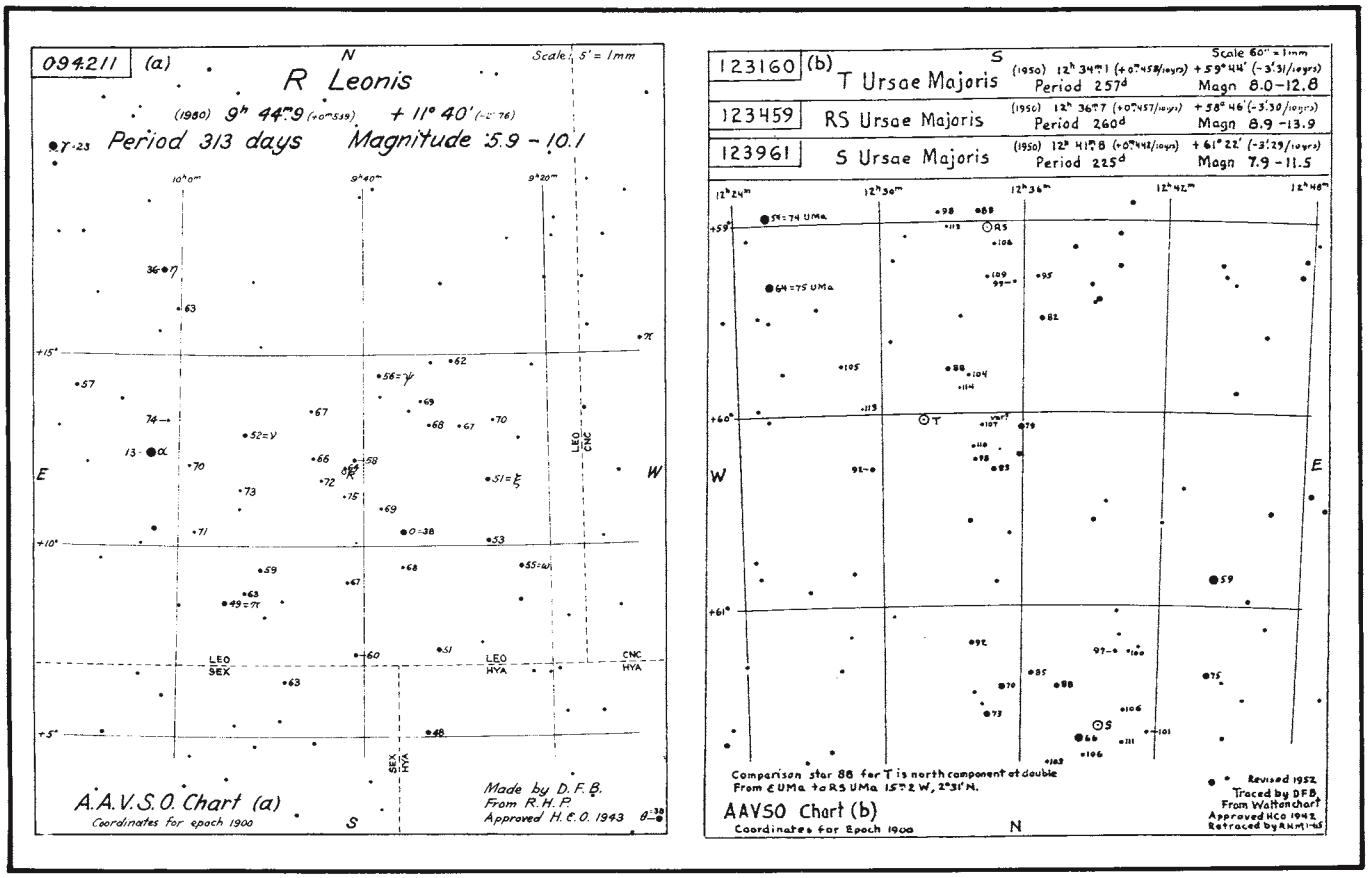
"As soon as darkness fell," Leslie wrote, "I bundled up and, with telescope, atlas, and charts in my mittened hands, I went out to find my variables. Two hours later, when I returned half frozen to the fire, I had found not a single one.

"Nor was I any more successful on several succeeding nights and I was becoming more and more discouraged. Finally, however, on the night of March 1, 1918, I set the telescope up near the northeast corner of the house to keep out of the wind and got out my chart of the variable, R Leonis. I pointed the telescope at the fourth-magnitude star Omicron Leonis and, using it as a base of operations, I started exploring the adjacent territory. To my great delight, about a minute later and just a little more than one field to the northeast of Omicron I found the tiny triangle of stars with R, my first variable, forming one angle precisely as shown on the chart.

"Why had success been so long in coming? Simply because I had no mental image of what to look for. I had not bothered to figure out just how much of the chart area was covered by the instrument's field of view. After this experience I soon made a wire ring which could be moved about over my charts to show me just what my telescope was seeing."

On the night of May 9, 1980, Peltier recorded his last variable star observation. When he died peacefully the next evening, he had left a legacy of over 133,000 variable star





Above are charts for all four of the variables in this issue's column. Note that north is at top for R Leonis. We acknowledge the AAVSO's observational data sent by the director, Janet A. Mattei.

observations — a most prolific and inspiring career. And it all began with a single observation of a nondescript red-giant star in Leo.

So it's that simple then? Just start with R Leonis and thousands of observations will flow with ease? Well, not quite. More than the numbers, Peltier had the secret ingredient of perseverance, a sense of commitment both to the variables he loved and to the spirit of scientific inquiry. He was primarily interested in how his variable stars behaved, and the large numbers of estimates naturally followed.

In this spirit, why not try observing R Leonis for yourself? Using the "a" chart, work your way from Alpha Leonis toward Omicron, the magnitude 3.8 star near the chart's center. Should R Leonis be bright, you may spot it in binoculars

Star	Maximum	Minimum
R Leo	Dec. 16	July 31
T UMa	June 25	March 16 Nov. 27
S UMa	March 15 Oct. 27	July 11
RS UMa	Oct. 17	June 29

and you should also remember that all AAVSO "a" charts are designed for a non-inverted field. Now with the "b" chart, find Omicron Leonis with your telescope. "B" charts offer inverted views to match those in a telescope; use a low power eyepiece for the widest possible field.

The Big Dipper Trio

123961 S Ursae Majoris, 123160 T Ursae Majoris, 123459 RS Ursae Majoris. For no really logical reason, I have always had a special feeling for these three variables in Ursa Major. A single "b" chart suffices for all of them at their brightest and, in a telescope of sufficiently wide field, you can see all of them at the same time. And from northern latitudes these stars are observable all year round. But aside from that, these are "average" Mira stars and, while bright S is fairly easy, T and RS are quite difficult when they're faint.

Like an out-of-step singing group, these three stars seem to perform to the mysterious beat of their own drummers. Note that the periods of T (257 days) and nearby RS (260 days) are only three days apart which means that over periods of time they appear to vary in sync with one another! S UMa, with a somewhat shorter period (226 days), appears to be somewhat off, like the penultimate chord of a Bach fugue. Again, the symphonic analogy seems to be coincidental. But as observers, we look for ways to add rhythm to our work, and even though the cosmic theme is somewhat illusory, it does add a certain zest to our view of the stars in this corner of the Dipper.

A Note on Recording

For professional astronomers interested in data on Mira stars, our visual variable star estimates are almost unacceptably subjective. As photometers operating in the visual spectrum, our eyes are far from ideal instruments since they are connected to our nonobjective brains. Too often we may make the mistake of basing an estimate on our recall of what the star looked like one or two weeks ago.

To help reduce the level of bias, I suggest that you record your observations twice. Out in your observatory, or at the telescope, keep a notepad with a fresh, blank sheet of paper on which you record your variable estimates. Do not prejudge your work by looking at your last count. Then, when you've gone inside after your session at the scope, add your estimate to the others for that star during the month.

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Scanning the Literature

October-December 1983

The *Publications* of the Astronomical Society of the Pacific (PASP) occasionally contain review articles which summarize research. Two such reviews have appeared recently.

The first is "Centaurus A," by Kate Ebneter and Bruce Balick of the University of Washington (*PASP* **95**: 675, October). Centaurus A, or NGC 5128, is one of the most intensively studied galaxies in the sky; with an integrated V magnitude of 7.0, it is also one of the brightest. The authors argue that its many observed features are typical for active elliptical galaxies, and it should not be considered a unique — or even particularly unusual object — as it is usually portrayed. Many of its peculiarities are visible simply because it is close; these details would not be seen in fainter, more distant galaxies like it.

NGC 5128 is a member of the class of dusty ellipticals of which about 90 are known. It is also a radio source (Centaurus A), but as such it is not especially luminous — sources are known that are a hundred times brighter at these wavelengths. Moreover, jets of matter seeming to emanate from the nucleus are seen also in other galaxies.

But the authors stress that just because it is a relatively normal object, it is not unimportant: Its proximity allows us to study the galaxy in more detail than any other active galaxy. Their review article cites about 130 references to research, nearly all published in the last ten years. There are also maps and photographs of NGC 5128 at all wavelengths from the X-ray to the radio.

Another review summarizes matters on quasars: "QSO's: Recent Clues to Their Nature," J.B. Hutchings (*PASP* **95**: 799, November). The average quasar is as bright as a bright galaxy. Placed at a distance of 10 parsecs, a quasar would be as bright as the Sun. Like Centaurus A, quasars have been observed in all the regions of the spectrum. The emerging model for a QSO is a supermassive black hole at the nucleus of a galaxy. Their large, rapid variations in brightness suggest that the energy source of QSO's cannot be much larger than a few hundredths of a parsec (about one light-month) across. Yet the mass required to generate the observed luminosity is something like 100 million solar masses — enough for a small galaxy. The review paper also gives optical and radio maps of several quasars.

For those with a bent toward photometry, an excellent lightweight design is shown in "A Portable Telescope, Photometer, and Data-Recording System" by Richard L. Baron, Edward W. Dunham, and James L. Elliot (*PASP* **95**: 925, November). The "portable telescope" in the set-up is a C14. The two-channel photometer as mounted on the telescope weighs less than 20 pounds, and is able to record starlight from the visible ultraviolet out about 3 micrometers in the infrared. The electronics and recording apparatus are specifically designed for high-speed occultation work, for which the authors are well known — Elliot was one of the principals involved in the discovery of the ring system of Uranus.

A color-magnitude diagram for a nearby galaxy is analyzed in "The Carina Dwarf Spheroidal — An Intermediate Age Galaxy" by Jeremy Mould and Marc Aaronson (*Astrophysical Journal* **273**: 530, October 15). The authors used a CCD camera to obtain photometry of stars to V magnitude 24 in this southern galaxy. The authors derive a distance of about 90 kiloparsecs, roughly twice the distance to the Magellanic Clouds. The color-magnitude diagram shows the giant branch and main-sequence turnoff features characteristic of young metal-poor stars. The bulk of the stars are 7.5 ± 1.5 billion years old, and the fraction of population II stars — which would be about 16 billion years old — is small. (Compare this with the results of similar work for NGC 147 in *Deep Sky 5*, page 36.) The authors conclude that these observations make the galaxy a contender for an object "which did not form until the universe was old."

SKYMAP is a computer-based catalogue of data on all stars brighter than magnitude 9.0. (Amateurs are becoming familiar with part of this catalogue in the excellent *Sky Catalogue 2000*.) Some interesting statistics about the catalogue are presented in "Stellar Number Densities for Magnitudes 0.0-9.0 from SKYMAP" by Steven F. McLaughlin (*AJ* **88**: 1633, November).

Using version 3.1 of SKYMAP, McLaughlin presents tables and charts showing the distribution of stars in terms of B-V color, galactic latitude, the distance to the nearest neighboring star, and other correlations. One table gives the whole-sky count of stars in quarter-magnitude bins: 7 stars are brighter than V = 0.25, 18,265 stars have V = 7.0, and there are 163,420 stars down to V = 9.0, where the catalogue becomes incomplete. In terms of spectral type, out of a total of 248,650 stars, only 394 are of type O, but 65,244 have spectral type K. There are 1447 luminosity class I supergiants, but 107,778 class V main-sequence stars. In terms of sheer numbers, then, the Galaxy near us is dominated by stars intrinsically fainter and less massive than the Sun.

One of the more bizarre members of the astrophysical zoo lies in the Large Magellanic Cloud. A spectroscopic study of it is presented in "The Nature of R136a, The Superluminous Central Object of the 30 Doradus Nebula," by Blair D. Savage, Edward L. Fitzpatrick, Joseph P. Cassinelli, and Dennis C. Ebbets (*ApJ* **273**: 597, October 15). In the past few years some have suggested that this object is either a single star of such great mass that it strains current theories of stellar structure to explain it, or (less probably) that it is an aggregation of many smaller but still exceedingly bright stars. The spectra used were obtained by the International Ultraviolet Explorer satellite. The spectra give evidence for a very hot star or small cluster of very hot stars. If the object is a cluster, the ultraviolet data indicate there must be about 30 type O and WN (Wolf-Rayet with nitrogen emission lines) stars in a region only 3 arcseconds diameter — which corresponds to less than 1000 AU at the distance of the LMC.

The authors note that "such a cluster would consist of 30 of the rarest stars found in galactic systems and have a mass density about a thousand times higher than any known region." They consider it more probable that there is a single superluminous star, or a small group of such stars. If the source is a single star, then R136a has a luminosity about 60 million times that of the Sun, a mass 2100 times larger, a diameter 50 times larger, and a surface temperature more than ten times hotter (75,000° K). Mass would be streaming off the star at a rate of about 0.0005 solar masses per year. While all of this is not impossible, it is not likely either — such a creature has an evolutionary lifetime from start to finish of only two million years. Thus R136a remains an unsolved puzzle.

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Core of the Rosette Nebula

Kitt Peak National Observatory photo